STAFF REPORT

1997 Global Climate Change

Greenhouse Gas Emissions Reduction Strategies for California Volume 2

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CALIFORNIA ENERGY COMMISSION

Pete Wilson, *Governor*

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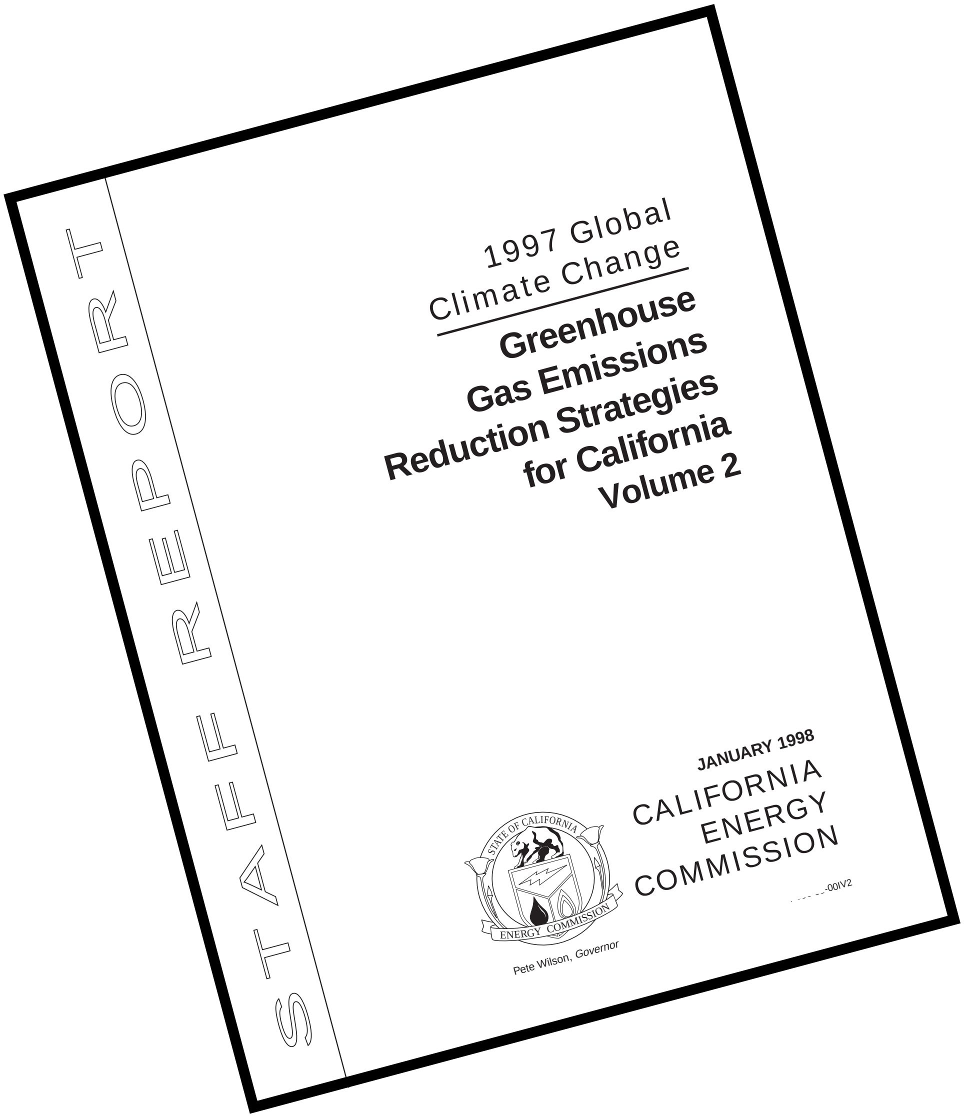

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1997 GLOBAL CLIMATE CHANGE REPORT
GREENHOUSE GAS EMISSIONS REDUCTION STRATEGIES
FOR CALIFORNIA

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Companion documents and documents referenced in this report include:

1) *Appendix A: Historical and Forecasted Greenhouse Gas Emissions Inventories for California*
2) *Appendix B: California's Greenhouse Gas Emissions Inventory, 1990 (March 1997), P500-97-004;*
3) *Electricity Report 94 Forecast of Uncommitted Demand-Side Management, Appendix A, Part I: Electricity Supply Assumptions Report, Section C (A-I-C) (November, 1995), P300-95-002A;*
4) *Assessment of the Greenhouse Gas Emission Reduction Potential of Ultra-Clean Hybrid-Electric Vehicles, California Air Resources Board, December, 1997.*

Appendix A is included as a volume of this report. The other documents are available from the California Energy Commission's Publications Unit.

Chapter I

Goals of the 1997 Global Climate Change Report

The Greenhouse Effect

Over the past 20 years, the potential for man-made emissions of greenhouse gases to damage the earth's atmosphere has become an issue of increasing concern to scientific communities and leaders of the world's industrialized nations. For billions of years, naturally-occurring greenhouse gases, primarily carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), tropospheric (lower atmosphere) ozone (O_3), and water vapor have maintained the balance of the earth's atmosphere, stabilizing temperatures in a range that allows life as we know it to exist. Now, in the last days of the 20th Century, evidence is growing that anthropogenic sources of these gases have the potential to substantially alter that balance, and global climate patterns, posing significant economic and environmental risks to all nations. In December, 1995, the United Nations' Intergovernmental Panel on Climate Change, which includes over 2,500 scientists, issued its report stating that "the balance of evidence suggests a discernible human influence on global climate."[1]

Primary man-made causes of greenhouse gas (GHG) emissions include fossil fuel combustion for energy; extraction and transportation of oil, natural gas and coal; deforestation; decomposition of waste in landfills; manufacturing and industrial processes; increases in populations of domestic ruminant animals; and biomass combustion in forests and agriculture. Carbon monoxide is not actually a greenhouse gas, but is a precursor, chemically reacting with other emissions to increase tropospheric concentrations of methane and ozone, both significant GHGs. Ozone, which acts as a solar radiation screen, is also decreasing in the stratosphere, allowing more ultraviolet radiation to reach the earth, increasing global warming effects.

Scientists estimate that human-caused combustion of over 6.5 billion tons of carbon per year results in about 60 percent more CO_2 than the earth's oceans and plants now can absorb.[2] Atmospheric concentrations of greenhouse gases are at their highest levels in more than 200,000 years and rising, with most greenhouse gas concentrations expected to double by the years 2030 to 2050.[3] Carbon dioxide emissions have increased 30 percent during the past century and are increasing at roughly .5 percent per year. Methane emissions have doubled in the past 100 years and are increasing annually at about one percent. Over the same period, nitrous oxide levels have risen about 15 percent and are increasing .2 -.3 percent annually; other, more minor, GHG emissions have grown .2 to 11 percent per year.[4]

Some symptoms of this warming trend are currently being observed, including slightly increasing earth and ocean temperatures, rising ocean levels, changes in global precipitation, thawing of the Antarctic Ice Pack and melting glaciers.[5] During the past two decades, according to some climate experts, worldwide rainfall has been more intense and snowfalls more severe, with record flooding from Yemen to Nepal; hurricanes have been stronger and had more devastating results; and there have been unseasonal and prolonged droughts, resulting in crop failures and major forest fires from Texas to Mongolia, and killer heat waves from India to Chicago.[6] It has been well documented that, over the past century, average global temperature has increased approximately 1^0 Fahrenheit. The 11 warmest years this century have occurred since 1980, with 1997 the warmest recorded.[7] The global ocean level has risen approximately 6 inches, with the rate of rise increasing over the past 10 years, and global precipitation has increased at higher latitudes (in the United States, by about 6 percent) and decreased at lower latitudes,[8] consistent with expected global warming effects.

Although there are numerous scientific uncertainties about the locations, timing and magnitude of worldwide climate changes, temperature changes predicted by the middle to the end of the coming century [a "best guess" average of 3.5^0 by the Intergovernmental Panel on Climate Change (IPCC)], could have substantial global effects. If the expected temperature increases were to occur, ocean levels could rise by two to three feet or more, surface supplies of water could decrease, winter flooding could increase, and water pollution could become more severe. Such climate changes would flood coastal areas in the United States and other nations, disrupt agriculture, and cause severe droughts.

Worldwide Responses to Potential Global Climate Change

In 1990, the United Nations General Assembly established the Intergovernmental Negotiating Committee for a Framework Convention on Climate Change (FCCC). The FCCC agreement was adopted in 1992 at the Framework Convention in Rio de Janeiro, where 160 countries became signatories, including the United States; the agreement was ratified by the U.S. Senate the same year. The initial agreement established voluntary goals to reduce GHG emissions to 1990 levels by the year 2000--goals which, at this point in time, will clearly not be achieved. Since 1992, two additional major international conferences (Conference of the Parties) have been held, at which countries have been urged to agree to more binding restrictions on greenhouse gas emissions. During summit meetings of leading industrial nations during the summer and fall of 1997, several European nation leaders agreed, conceptually, to adopting binding targets for reducing anthropogenic sources of greenhouse gases from 1990 levels by an average of 15 percent, by the year 2010.

Throughout these discussions, the United States proceeded more cautiously than the other industrialized nations toward establishing binding emissions reductions targets. However, in an address to the United Nations General Assembly in June, 1997, President Clinton committed the nation to setting "realistic and binding limits that will significantly reduce our emissions of greenhouse gases" and to ". . . lay out the scientific facts. . .and the economic facts so that (citizens of the U.S.). . . will understand both the benefits and costs."[9] A key issue raised by the United States was that developing nations, where growth in emissions is increasing most rapidly, should be required to participate in any international treaty on Global Climate Change emissions reductions.

At the most recent Conference of the Parties (COP3), held in December, 1997, in Kyoto, Japan, several days of intense negotiations resulted in adoption of a protocol to the agreement by 39 industrialized nations to reach specified emissions reduction targets. Under the protocol, the U.S. agreed to reduce emissions to 7 percent below 1990 levels between the years 2008 and 2012. The Kyoto Protocol also allows for a system of emissions trading among developed nations and for CO_2 reductions from a country's reforestation efforts, based on newly-planted trees and their carbon-sequestration benefits. Finally, the parties agreed to defer the question of developing countries' participation until the next meeting, scheduled for November, 1998, in Buenos Aires. Many other details remain to be worked out, including appropriate compliance mechanisms and potential penalties for non-compliance. All nations involved have from March 15, 1998 through March 15, 1999 to ratify the Kyoto Protocol; the U.S.' signature will require ratification by Congress.

According to the U.S. Department of Energy, under the target adopted for the U.S. (7 percent below 1990 levels), the United States would be required to reduce emissions by about 30 percent below a business-as-usual scenario by 2012. Without such reductions, the Energy Information Administration has reported that U.S. carbon emissions are expected to reach 34 percent above 1990 levels by 2010, and 45 percent by 2020. Concurrently, energy consumption in the U.S. is expected to increase by nearly 30 percent by the year 2020.

California's Response to Global Climate Change Issues

Over the past decade, California has been at the forefront in the U.S. in assessing the potential effects of increasing greenhouse gas emissions. Emissions of carbon dioxide account for nearly 88 percent of California's greenhouse gases, in line with national proportions. However, California's emissions sources differ somewhat from the rest of the nation. Nationally, in 1994, electricity generation sources accounted for 39 percent of carbon-related emissions, industry 17 percent, and transportation 32 percent. In comparison, California's electric generation sector (utility and non-utility) produced only 16 percent of emissions in the state, and industry 14 percent, but transportation produced nearly 57 percent. Nationally, and particularly in the West, emissions from the transportation sector are growing the fastest.[10]

In 1994, California's per capita CO_2 emissions were nearly 40 percent lower than the U.S. average. While a major portion of this difference is due to California's climate, fewer high- energy consuming industries, higher reliance on natural gas, and negligible coal consumption, California's policies to reduce statewide energy use can be credited for about 10 - 15 percent of the difference. For example, lower emissions from electric generation result partially from far-reaching policies, since the mid-1970s, of promoting energy efficiency, encouraging natural gas generation to replace electricity, and supporting the development of renewable energy resources for electricity generation. While California's energy policies were adopted primarily to meet the most stringent standards for criteria air pollutants in the nation, and to promote economic and environmental benefits, many of these policies have had concurrent benefits for reducing CO_2 and other greenhouse gases. On the other hand, the state's extensive transportation infrastructure produces emissions from this sector that are over
20 percent higher than the national average.[11]

In 1988, the California Legislature (Assembly Bill 4420, Sher) directed the California Energy Commission to begin a study of the potential impacts of global warming trends on the state's energy supply and demand, economy, environment, agriculture, and water supplies and to develop policies for reducing these impacts. The Energy Commission's report was prepared in cooperation with other concerned state agencies, including the California Air Resources Board (CARB), Department of Forestry, Coastal Commission, Department of Food and Agriculture, and Department of Water Resources. Lawrence Berkeley Laboratory, Livermore Laboratory, and Envirosphere and Acurex corporations were also asked by the Energy Commission to provide technical input to the study. The report was widely reviewed, and comments were received by a broad spectrum of interests, including state and federal agencies, other states, business and industry, trade organizations, environmental interests, and the research community. The Energy Commission adopted its final report, *1991 Global Climate Change: Potential Impacts and Policy Recommendations,* and submitted it to the Governor and Legislature in November, 1991.

Adoption of California's *Global Climate Change Report* led to direction by Governor Pete Wilson for California to continue to explore issues surrounding the potential impacts of greenhouse gases on the state's environment and economy. The Energy Commission was reaffirmed as lead agency for these studies, with participation by other interests. In the spring of 1994, the federal Environmental Protection Agency (EPA) issued a Grant Opportunity Notice for proposals from states to prepare updated statewide inventories of greenhouse gas emissions and to develop and evaluate policies and strategies for reducing emissions. California, among other states, was selected and funded by EPA to carry out this study.

Goals of the 1997 California Global Climate Change Report

Based on a 1988 inventory of greenhouse gases in California, the *1991 Global Climate Change Report* discussed the potential effects of emissions on California's environment and major sectors of the economy, including the energy industry, agriculture, forestry, and transportation. The report also set forth a broad range of policy options and proposed strategies to reduce emissions in these areas, including:

1. Promoting energy-efficient technologies and strategies in the residential, commercial and industrial sectors;

2. Accounting for environmental externalities in assessing the costs of energy production, energy resource planning, and procurement;

3. Promoting development and integration of renewable generating technologies into the electricity system;

4. Promoting high-efficiency gas generation technologies;

5. Improving forestry, livestock and solid waste management and recycling programs;

6. Expanding markets for low-emission alternative fuels and vehicles;

7. Promoting research and development on biomass-based alcohol fuels;

8. Reducing vehicle miles traveled in personal vehicles, through promoting improved and expanded transportation alternatives, vehicle miles traveled fees, and other highway use fees; and,

9. Expanding land use planning to incorporate long-term transportation needs and promote strategies for better management of transportation demand.

Based on new statewide GHG emissions inventories and forecasts, the current *1997 Global Climate Change Report: GHG Emissions Reduction Strategies for California* updates and further evaluates the significant policy recommendations and strategies for all energy-economic sectors proposed in the 1991 report. In addition, this report explores recent major energy policy changes occurring in California that could potentially affect GHG emissions and modify some conclusions previously reached. Major changes include:

1) restructuring of California's electric utility industry in 1996-97, for transition to a competitive energy supply and services market;

2) provision by the state of transition-phase funding to support the continued development of renewable energy resources and energy efficiency programs; and,

3) state and federal policy changes affecting the transportation sector, including low-emission vehicle requirements, the use of reformulated gasoline, and changes in regulations requiring congestion and transportation demand management efforts.

While the long-term effects of these policy changes on greenhouse gas emissions and numerous other issues cannot yet be evaluated quantitatively, some potential effects are examined in Chapter II of this report.

Chapter III presents a brief summary of the technical basis for the report, *Historical and Forecasted Greenhouse Gas Emissions Inventories for California (Appendix A).* The chapter also discusses non-GHG emissions that could contribute to global climate change. In Chapter IV, strategies to reduce greenhouse gases produced from electric generation and residential, commercial, and industrial end uses are evaluated with regard to their potential effects and current status of implementation. Strategies discussed include energy efficiency in end-use sectors, new technologies for oil and gas production, policies relating to electricity resource planning, the development and use of high-efficiency gas generation technologies, and development and integration of renewable resources into electricity generation. Chapter V deals with strategies to reduce other major sources of GHG emissions, including forestry, livestock, and solid waste management. Strategies relating to California's transportation sector are discussed in Chapter VI. Chapter VII is a summary of evaluations and conclusions presented in Chapters II - VI of the report.

Two technical appendices to this report explain the methodologies used for inventorying California's GHG emissions and present inventories and forecasts for emissions from each energy-economic sector. They include Appendix A: *Historical GHG Emissions Inventories and Forecasts for California (*emissions inventories through 1994 and forecasted emissions for the years 2000, 2005 and 2010) and Appendix B: *1990 GHG Emissions Inventory for California* (the base year, as required by EPA). Appendix C contains data developed for the *1994 Electricity Report* which was referenced in Chapter IV of this report.

ENDNOTES

1. *Intergovernmental Panel on Climate Change (IPCC) Second Assessment Report*, 1996.

2. California Energy Commission, *Global Climate Change: Potential Impacts and Policy Recommendations*, December, 1991, p. 1-4.

3. *IPPC Report*, 1996.

4. California Energy Commission, *Global Climate Change Report*, 1991, p. 2-14.

5. For example, in January, 1995, a vast section of ice (about the size of Rhode Island) broke off the Larsen ice shelf in Antarctica; two months later, a second major shelf collapsed.

6. Gelbspan, Ross, *The Heat is On*, quoted in The Sacramento Bee, Forum, page 1, July 13, 1997.

7. Data from National Climatic Data Center, National Oceanic and Atmospheric Administration, Ashville, N.C., January, 1998.

8. *IPPC Report*, 1996.

9. Clinton, President William Jefferson, text of address to the UN Special Session on Environment and Development, New York City, June 26, 1997.

10. Western Interstate Energy Board, "Global Climate Change, Report to the Western Governors' Association," June, 1997.

11. Carbon dioxide emissions from transportation are directly proportional to the amount of fuel consumed; while California's emissions controls have reduced the release of criteria pollutants from personal vehicles, each gallon of gasoline consumed still releases about 20 lbs. of carbon in tailpipe emissions.

Chapter II

Current California Context for the Global Climate Change Report

Introduction

Since publication of the *1991 Global Climate Change Report (1991 GCC Report)*, there have been several new energy, air quality, and transportation policy initiatives in California which could modify the conclusions reached in the 1991 report. These policies may affect California's greenhouse gas emissions and require refinement of emissions-reduction strategies. The changes are too new to predict long-term effects with certainty, but their consideration is essential to this study.

Chief among these initiatives is California's landmark restructuring of how electric utilities provide energy supplies and services. On December 20, 1995, the California Public Utilities Commission adopted its order on deregulating and restructuring the electric utility industry to allow for competitive, market-based electricity supplies and services in the state. On September 23, 1996, the Governor signed Assembly Bill 1890, the Electric Industry Restructuring Law, which further refined deregulation activities and established requirements for the transition to a competitive market.

The law created a new entity, the Independent System Operator (ISO) to oversee statewide electricity dispatch and system reliability. It set in place a competitive bidding process, facilitated by another new entity, the Power Exchange (PX). As of April 1, 1998, customers of investor-owned utilities (IOUs) will be able to select among suppliers, instead of being limited to their franchise utility. Finally, AB 1890 set minimum funding levels for energy efficiency programs from 1998 to 2002 and established broad funding and allocation guidelines to support renewable energy resource technologies during the four-year transition period. The Energy Commission was charged by the legislature to assist in establishing new authorities and procedures for electricity supply and distribution; to take steps to ensure the continuation of energy efficiency programs and funding for renewable energy resources development over the transition period; and to analyze the potential impacts of restructuring on California, as the state moves toward a market-based system.

These changes in how energy is produced and supplied to California's electricity customers may affect some conclusions reached in the *1997 Global Climate Change Report*. The changes may bring about adjustments in statewide energy efficiency programs, in the contribution of renewable resources to the electric generation system, and in funding for energy research and development. Elements of California's restructuring initiative that may affect Global Climate Change emissions reduction strategies are discussed in detail in the next section of this chapter.

In addition to a new concept of providing energy supplies and services, California has seen major policy changes related to the state's transportation system. Many of the state's metropolitan areas suffer from some of the worst air quality in the nation. Transportation is a major contributor to these problems, as well as the primary contributor to carbon dioxide emissions, and California has struggled for many years to develop strategies designed to reduce transportation-generated air pollution. Since the publication of the *1991 GCC Report*, California has developed low-emission vehicle (LEV) requirements and a master plan for infrastructure to support development, production, and operation of LEVs, and has adopted requirements to use reformulated gasoline in personal vehicles. The state has also rescinded some regulations that established transportation demand management programs in the 1980s and early '90s and has reduced requirements for congestion management plans designed to relieve the state's traffic congestion and air pollution problems. The implications of these actions for greenhouse gas emissions-reduction strategies are discussed further in this chapter.

Through this current study and on an ongoing basis, the Energy Commission staff is assessing the implications for GHG emissions of energy production and supply by the electricity and natural gas industries and energy use by all economic sectors, including the state's transportation system. Electric utility industry restructuring and new transportation initiatives represent major changes in energy policy for California. The staff will continue to evaluate the potential impacts of these changes on the state's greenhouse gas emissions, and to develop and promote strategies to reduce their potential environmental and economic consequences in the state and in the nation.

Restructuring California's Electric Utility Industry

Beginning in April, 1998, Californians will be able to choose their electricity supplies and services in much the same way as they choose a long-distance phone service. Governor Wilson's signature on AB 1890 in September, 1996, changed the state's major energy supply system from a regulated monopoly to a competitive, market-based structure. Historically, three large investor-owned electric utilities (IOUs), Pacific Gas & Electric, Southern California Edison and San Diego Gas & Electric, have operated as regulated monopolies in defined service areas. Each company is obligated to provide (either generate or procure) sufficient electricity to meet all of its customers' demand. Each IOU is also required to have sufficient reserve capacity available to prevent power outages due to transmission line failure or power plant shut-down. Electricity is delivered over a large network of power lines known as the transmission and distribution grid; each IOU is responsible for dispatching electricity and maintaining system reliability for its own portion of the grid. About 25 percent of Californians are served by municipal (publicly-owned) utilities, which have the same general duties as IOUs but are independently governed by individual boards.

Restructured System

Since January 1, 1998, as mandated by AB 1890, three major changes have occurred with regard to how electricity is produced and sold. The first is that statewide electricity dispatch and system reliability oversight is performed by a new centralized entity, known as the Independent System Operator (ISO). The second big change is that the price paid for electric generation, previously regulated by the California Public Utilities Commission, is now allowed to rise and fall according to market forces. An electric power market is being established and prices will be determined by competitive bidding, facilitated by another new entity known as the Power Exchange (PX). The third major change is that IOU customers are allowed to select among suppliers, instead of being limited to their franchise utility. While municipal utilities are not subject to AB 1890, these utilities may voluntarily allow their customers to choose among electricity suppliers.

Only the generation component of electric service is substantially open to market competition, with transmission and distribution still subject to bid. Finally, AB 1890 required that rates be frozen for all sectors at June 10, 1996 levels during the transition period and that, on January 1, 1998, rates for residential and small commercial customers be reduced by 10 percent from those in effect on June 10, 1996.

Independent System Operator

Pacific Gas & Electric, Southern California Edison, and San Diego Gas & Electric will continue to own their transmission facilities, but turn operation of them over to the Independent System Operator (ISO). The ISO is independent of the utilities and is regulated by the Federal Energy Regulatory Commission. The ISO will function like an air traffic controller for energy, making sure electricity is transmitted throughout the state reliably, safely, efficiently and on a non-discriminatory basis. The ISO will require that all direct-access arrangements be scheduled by a Scheduling Coordinator (SC)-- the PX, a utility, or an aggregator, broker or marketer-- and that the SC provides a balanced schedule to keep its energy use and/or generation in synch over the 24-hour period, helping the ISO to avoid over-generation or unnecessary load shedding.

Power Exchange

The Power Exchange (PX) functions as an auction for power generation and will create a "pool" or "spot market," where price information is publicly available. The PX will solicit bids from electricity generators and choose the lowest bidders, until the PX has enough supply to meet its obligations to provide power. It will pay generators the price of the most expensive generator needed to fill its demand, and PX prices will change on an hourly basis. Many customers will pay for electrical power based on this price, either directly through their distribution utility or through a private power supply contract with terms that are pegged to the PX price. Thus, consumers who choose to enter into private contracts for power, where the terms, conditions and price are not public knowledge, may use the public information from the PX to gauge the attractiveness of supply or service offers they receive. In order to bring about a robust market, the three IOUs must sell all of their power to the PX and buy power from the PX to resell to their customers during the four-year transition to a fully competitive market. This requirement is designed to ensure fair competition among utilities and other electricity suppliers.

With regard to generation, the electric utilities will continue to have an "obligation to serve the public" in the performance of their distribution function. The electric utilities will continue to operate the distribution lines which link customers to the transmission system to deliver electricity to homes and businesses, even if the customer chooses to purchase electricity from another company. The utilities are now known as utility distribution companies (UDCs) and are responsible for the reliable, safe delivery of electricity to the homes and businesses within their service area.

Potential Results of a Competitive Electric Industry

New and custom-tailored services will be offered to customers. Electricity producers, including utilities, should have an incentive to operate as efficiently as possible so that they can be competitive, remain financially viable, and earn a profit for their shareholders, and the expected increases in efficiency should produce lower electric rates in the long run. Each entity offering electric service to residential and small business customers must register with the Public Utilities Commission, and residential, commercial, agricultural and industrial customers will be able to buy electricity from any registered provider and have it delivered through the lines of their current distribution utility. Some suppliers may offer different rates for day and night, or for different seasons. Customers will be able to choose from a variety of pricing plans and a variety of electricity providers, although customers satisfied with their current utility may choose to continue purchasing their electricity from that company. Customers may choose to contract with their local government, an association, a broker or an aggregator to purchase electricity for them. Cost-conscious customers may choose to install a special meter, in order to purchase and use electricity when it is least expensive. A daily forecast of tomorrow's hourly electricity prices will be posted in the newspaper and on the Internet.

Under restructuring, utilities are seeking to collect a "competition transition charge," most of which will be collected through March, 2002, as a result of the following circumstances: Historically, electric customer rates have, in part, reimbursed utilities for their costs for building power plants and buying electricity from independent power producers to service their customers. The CPUC has reviewed and approved these costs as reasonable for many years, and authorized utilities to recover them through rates. Since some of the existing resources owned by utilities are expected to become uneconomical in a market-based industry and have been rate-based over long-term periods (are "sunk" costs), utilities will still be allowed to recover these costs during the first few years of the competitive electricity market. The theory behind this charge is that it will prevent customers who don't switch utilities from paying higher rates to their current utility, to make up for revenue lost from customers who do switch to a competing company. In addition, utilities are pursuing a bond issue for over $6 billion, repayable over many years, to compensate for these "sunk" costs, and are currently linking approvals of the issue by the Internal Revenue Service to their ability to provide the expected rate reductions to residential and small commercial customers. The effort by utilities to collect "competition transition charges" is currently under debate among a variety of interests in California and the subject of a petition for a measure on the ballot to be considered in the November, 1998, elections.

Potential Near and Long-Term Effects on Energy Generation and Use

The existing generation, distribution, and use of electrical energy in California and the other western states is a highly complex and interdependent system, emitting both criteria air pollutants and greenhouse gases. Its operation has been determined by many factors, including demand, energy prices, system reliability, and regulated rates of return. As California is restructuring its electricity industry to a competitive market, developers are positioning themselves to build and operate power plants in California based on new criteria. Restructuring and divestiture of existing generation facilities by electric utilities may change economic decisions regarding when to run, retrofit, refurbish, repower, replace, or retire existing powerplants. Consequently, generation patterns may change. Changes in electricity pricing will result in changes in the time and duration of use, and in overall demand. While changes in demand and generation are expected to occur, there is no certainty as to how they will affect fuel and energy use or air emissions from electricity generation and consumption.

Future Environmental Uncertainties

The Energy Commission believes that restructuring should be implemented in a manner that maintains existing levels of environmental quality; however, quantifying the potential environmental impacts of the restructured system has been difficult. Several questions remain about system structure and operation, such as: What will be the market clearing price at the PX? Will the market warrant construction of new facilities sooner or later? How will transmission congestion pricing affect system dispatch? And what units will remain “must-run” for reliability and voltage support?

Experts have expressed disparate views on the answers to these questions and, as a result, on the nature and extent of the likely environmental effects of electricity industry restructuring. Some experts believe that only minor, second-order effects on the location, size, and type of new plants and transmission lines seem likely; others anticipate an 8 to 10-year standstill in powerplant development; yet another view is that restructuring will lead to rapid technological change in the next 10 to 15 years, including the development of distributed energy resources. Any one of these scenarios potentially could occur, involving complex, indeterminate interactions with other aspects of the emerging market. California's ability to assess the results of changes from restructuring, particularly on air emissions, depends on the availability of accurate data and the modeling tools necessary to predict the dynamics of a highly complex, competitive market.

Most power plants use fuel, process cooling water, and emit waste streams which can affect the surrounding environment. Despite the potential for electricity generation and consumption patterns to change, the uncertainty about how the changes will occur contributes to the difficulty in forecasting restructuring's environmental effects. As an example, changes in criteria air pollutants and greenhouse gas emissions will, in general, result from changes in the way in which, and times when, the generation system operates. The following four variables could impact criteria air pollutant and GHG emissions:

- changes in the timing and level of customer demand;
- changes in operating hours and levels of operation of existing power plants;
- the timing and extent of new power plant construction; and,
- the use of distributed generation.

Electricity demand may change in response to the new market-based prices. Since the essential goal of restructuring is to gain system efficiency through market forces, all customer classes should eventually see price reductions. In turn, these price reductions are likely to result in an increased use of electricity. From an environmental perspective, increased demand can result in increased fossil fuel use and air emissions, depending on the type and timing of the increase and the type of generation used to meet marginal demand. The price differential between electricity and other fuels will also affect demand.

Increased operation of some existing fossil-fueled plants may result in increased air emissions. The operation of existing fossil units could increase if nuclear facilities decrease operation due to lack of competitiveness or early retirement. Increased operation and/or size could be the result of repowering existing fossil facilities. Increases in price differentials from one hour to the next will tend to decrease demand during periods of high prices. This will tend to reduce the use of currently-marginal units, which also tend to have relatively higher air emission rates.

Operation could also change due to the lack of timely, competitive resource additions, or changes in ownership due to divestiture of utility plants. The timing and extent of new power plant construction under restructuring is not known at this time. Two large plants filed applications with the Energy Commission in 1997, and three to four others are expected to file in 1998. Since these will be state-of-the-art, efficient natural gas facilities, which are subject to New Source Review (NSR) and Best Available Control Technology (BACT) requirements, they will operate with far lower air emission rates than existing fossil-fuel facilities.

The use of distributed energy resources (DERs) may prove more attractive in a competitive market to those seeking to increase the reliability of their power supply by self-generating. For the DERs that are fossil-fueled, some may have higher air emission rates than conventional large power generation technologies. Whether such increases are significant will depend on the location, number, and mix of DER technologies added to the system.

Restructuring the electricity industry will remain an ongoing activity for years. Continued public funding of "public-purpose" programs--subsidizing demand-side management (DSM), research, development and demonstration (RD&D), and renewable resource additions to electricity generation supplies--is an express requirement of restructuring during the four-year transition phase. California's Global Climate Change emissions-reduction strategies are inextricably linked to these public-purpose programs. The long-term efficacy of GCC emissions-reduction strategies, therefore, depends on the future industry environment remaining supportive of the activities that current public purpose programs support.

California energy policies have encouraged investments in utility DSM programs and favored programs that are cost-beneficial over a relatively long term and when spread out over all customers--those who participate in such programs and those who don't. With direct access, retail customers will be free to choose their electricity supplier, and utilities may perceive that any investment that raises their short-term commodity price for electricity will cause a loss of customers and revenue. If utilities are unable to recover DSM program costs from all customers, because some are now price-elastic, they may refocus their DSM efforts to include only measures that participating customers will choose as being cost-beneficial to them. Further, if utility shareholder incentives to offer peak and energy-savings programs are no longer mandated, they may be discontinued, or at least reduced in scope.

Information Needs

Energy regulators, planners and information providers need reliable information to plan effectively for and react efficiently to potential environmental changes due to restructuring Both current and historical data is needed, including data on the timing and levels of energy consumption, fuel types and use, short-and long-term generation levels and air pollutant emissions. Continuing efforts to quantify the effects of greenhouse gas emissions on the state's environment and economy warrant the collection of the most pertinent and accurate data available. Because energy use and potential environmental impacts are affected by both generation and end-use technology characteristics, data about emerging technologies is also important input to system models. Historical and current data is needed to develop and test analytical tools (including models) and to predict trends

Energy Efficiency Programs

Over the past two decades, California has encouraged business and private consumer investments in energy efficiency to reduce energy and environmental costs (including reducing emissions of greenhouse gases)[1] and to preserve future resources. These goals have been achieved through Energy Commission energy efficiency regulations for buildings and appliances, support for energy efficiency programs run by electric and natural gas utilities, and providing loans and implementing numerous energy efficiency projects for schools, hospitals, and the residential and commercial sectors. The Energy Commission has also carried out far-reaching public education efforts that have included:

1. presenting training workshops on energy-efficiency measures and technologies for the building industry, manufacturers, and service technicians

2. assisting utilities and the academic community to develop college-level and K-12 energy efficiency curriculums

3. carrying out energy conservation contests and awards for schools; and

4. providing general public education, which currently includes an Energy Information Home Page on the Internet.

Since the mid-1990s, the favored model for attaining energy efficiency goals has shifted away from purchasing least-cost energy efficiency resources with public funds and toward emphasizing sustainable "market transformations" in the energy efficiency services market. The new approach uses public funds to work directly with existing market players to reduce market barriers to the purchase of energy-efficient products and services, with the goal of ensuring more energy savings in the long term. Significantly greater leverage can be acquired by involving energy-efficient product suppliers and services in providing these public benefits than by providing cash to a select few who may or may not continue to market energy efficiency after the programs end.

Energy Efficiency Board

Legislation guiding restructuring of the electric industry in California (AB 1890) established an independent Energy Efficiency Board (EEB) to oversee development of energy efficiency programs for the years 1998 to 2002. The Board is currently developing the scope of programs and evaluation criteria to be used in assessing program success. AB 1890 allows the EEB only four years to make the private market for energy-efficient products and services fully operational and robust.

Expected Changes in Funding

AB 1890 also sets funding minimums for energy efficiency programs. For investor-owned electric utilities, the law sets a minimum funding level of $266 million for the period from 1998 to 2002. The amount required is less than the actual expenditures reached at the peak of utility program spending in 1994 ($335 million), but is roughly the same as the demand-side-management expenditures authorized by the Public Utilities Commission for 1996 ($240 million). Publicly-owned utilities are required to spend a share of their projected 1998 annual revenues on "public purpose" (including energy efficiency) programs. AB 1890 does not entirely determine the minimum expenditures for such programs by publicly-owned utilities, but it is likely that the final amount could be similar to the funding that municipal utilities used for those programs in 1994 ($70 million). While funding will be available for new types of programs, it is difficult to predict the effectiveness of the prototype market transformation programs, particularly in the short term.

Potential Near and Long-Term Effects on Energy Efficiency Programs

For the short-term, changes in energy prices, program funding and program orientation could engender feelings of uncertainty and reluctance among major residential and commercial sector investors to participate in any new programs to increase energy efficiency and result in reduced savings. In addition, there is a risk that "market transformation-style" programs will not produce measurable energy savings in the near term. Efforts to eliminate long-standing market barriers are seen as inherently more risky than the standard method of providing cash to the customer for the desired level of efficiency investment. Results of these programs are also more difficult to track, at first, since the focus is on changing market processes and the purchasing behavior of consumers, rather than directing or influencing specific market results, such as sales of specific products. Further, should energy prices decline significantly, investment in energy-saving technologies and behavior by residential and commercial consumers could lag, reducing efforts to reduce CO_2 and other air emissions.

Similar results are expected in the industrial sector. Efforts by California’s largest energy-consuming industries to reduce the cost of electrical energy were a major catalyst in the CPUC's plans, and legislative actions, to deregulate and restructure the state's energy market. The act has heightened industry’s awareness of the potential to reduce electricity costs, but could have two possible, diametrically-opposed outcomes. Demand for energy efficiency and, consequently, emissions improvements may decrease, as potentially-reduced energy costs increase payback periods for efficiency measures. Conversely, restructuring has alerted industries to the potential to reduce energy costs, which could result in efforts both to seek alternative, less-costly supplies and to adopt energy efficiency measures. In addition, the potential exists for changes in funding for energy efficiency programs to either positively or adversely affect the industrial sector.

If the Energy Efficiency Board succeeds in its purpose, and market transformation occurs in four to five years, long-term prospects are good for significant reductions in energy use and associated CO_2 emissions. Based on a forecast of potential CO_2 emissions to the year 2010, Chapter IV of this report assesses the potential of California's energy efficiency programs in the residential and commercial sectors as strategies to reduce emissions and describes scenarios of different levels of savings that might occur, depending on the funding allocated to efficiency programs and their overall effectiveness. The chapter also describes California's participation in programs specifically designed to reduce GHG emissions from the state's largest industries.

Renewable Energy Technologies

Transition-Phase Funding for Renewable Technologies

AB 1890 directs the collection of $540 million from investor-owned utility (IOU) ratepayers, from 1998 to 2002, to support existing, new, and emerging renewable-resource electric generation technologies. The legislation also provides $62 million per year for public goods research and development on energy-related technologies. The renewable resources funds are to be used to: [2]

1. support the operation of existing, and the development of new and emerging, in-state renewable resources;

2. support the operation of existing renewable technologies that provide fire suppression benefits, reduce landfill materials, and mitigate open-field agricultural burning; and,

3. support operation of existing innovative solar thermal technologies that provide peak generation and reliability benefits.

AB 1890 directed the Energy Commission, by March 31, 1997, to make recommendations to the Legislature regarding market-based mechanisms to allocate the funds. Programs recommended were to include options and implementation mechanisms that: [3]

1. reward the most cost-effective renewable generation, while fostering a market for renewable resources;

2. implement a process for certifying renewable resource providers, to provide them with funding support and to allow accelerated direct access privileges to customers that buy 50 percent or more of their electricity from certified providers;

3. allow customers to receive a rebate from the renewables fund;
4. allocate at least 40 percent of total funds to existing renewables, and at least 40 percent to new and emerging renewables; and,

5. use financing and other mechanisms to maximize the effectiveness of the available funds.

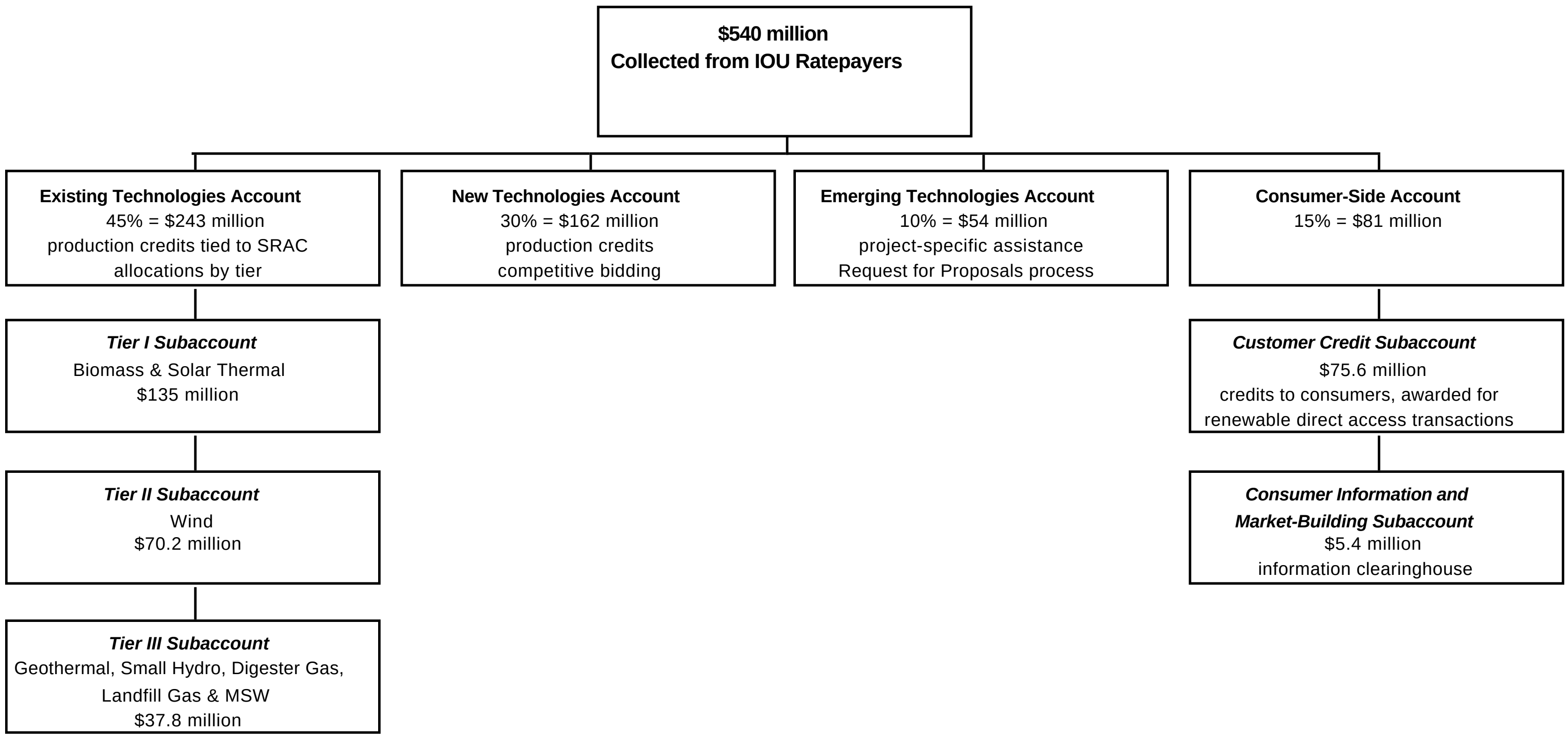
Policy Report on AB 1890 Renewables Funding (Renewables Report)

The Energy Commission's *Policy Report on AB 1890 Renewables Funding (Renewables Report*[4]) was approved by the Legislature on October 12, 1997. The report includes allocation and distribution strategies as summarized in Figure II.1. Since the market characteristics of the renewables industry vary substantially, the report recommends that AB 1890 renewables funding be provided through four different mechanisms and four different types of accounts, designed to provide balanced support. Each variety of technology status --existing, new, and emerging-- is assigned an account, with a fourth, the consumer-side account, designed to help develop a consumer-driven market for renewable generation.

The existing technologies account is allocated 45 percent of the $540 million for the support of existing renewables (with the provision that these funds may roll over to other uses if not needed). New renewable facilities are allocated 30 percent (approximately $160 million); emerging renewable technologies--those that need commercialization support, but are beyond the research and development stage--are allocated 10 percent. Since new renewable generation supported by AB 1890 funds must eventually be competitive in the new power exchange or direct access markets,[5] the report proposes neither specific technology allocations (set-asides) nor tiers for new renewables. Instead, it sets up competitive bidding mechanisms to reward the most competitive and cost-effective new renewable generation, without specifying technologies to be supported.

The remaining 15 percent of the funds is allocated for development of a consumer-driven renewables market, and includes a customer-credit sub-account (14 percent), funds which will be returned as a bill credit to consumers who purchase renewable energy from existing, new, or emerging technologies. One percent of the funds is allocated to the consumer information and market building sub-account.

Figure II.1: Proposed Allocation of AB 1890 Renewables Funds



Distribution Mechanisms

As summarized in Table II.1, the AB 1890 Report contains separate distribution mechanisms for the four accounts. The mechanisms for existing technologies, new technologies, and customer-side accounts are all per-kilowatt-hour (kWh) incentives. The distribution method for emerging technologies will consist of project-specific mechanisms, to be determined by criteria for competitive Requests For Proposals (RFPs). The proposed distribution mechanisms are market-based, simple, and flexible, allowing for market players to decide whether to expand or reduce operations, determine which new technologies will be built, and choose whether to purchase electricity from renewable suppliers or from traditional sources. The mechanisms proposed include simple caps and react to market clearing prices to automatically avoid most overpayment or underpayment issues.

Table II.1: Summary of AB 1890 Distribution Mechanism

Distribution Mechanism	Features
1. Per kWh Production Incentive (Existing Technologies Account)	• amount determined by lesser of: 1) target prices minus market clearing prices 2) available funds divided by generation; or 3) specified production incentive caps • payments made on a monthly basis • rain check provision for scheduled plant improvements • three subaccount "tiers," with different target prices and caps
2. Per kWh Production Incentive (New Technologies Account)	• allocation to specific suppliers determined by a simple auction • funds distributed over a five-year period • payments made on a monthly basis
3. Project-Specific Support (Emerging Technologies Account)	• distribution mechanism determined on a project-by-project basis • could include interest rate or capital cost buy-downs, customer rebates, and other forms of assistance
4. Per kWh Consumer Incentives (Consumer Credit Subaccount)	• amount determined by lesser of: 1) available funds divided by eligible renewable generation; or 2) a 1.5 cent/kWh incentive cap • payments made monthly

The existing technologies account distribution mechanism is a simple cents/kWh payment, tied to the relationship between target prices and the market clearing price for electricity, along with the number of kWhs generated. Target prices are fixed-cents/kWh levels established for the three tiers in the existing technologies account. They are set to reflect a competitive energy price for the technologies in the tiers, accounting for their approximate average costs and other revenue streams (e.g., tax credits and capacity payments). Payments are made only when the “market clearing price” falls below the target price for a tier, minimizing any unneeded support from the fund.[6] The highest target price, for Tier 1, ramps down to equal the target price for Tier 2 by 2001. Suggested target prices and production incentive caps for the existing technologies account are summarized in Table II-2.

Table II.2: Target Prices and Payment Caps for Existing Technologies (Cents per kWh)

		1998	1999	2000	2001
Tier 1 (Biomass,* Solar Thermal)	Target Price	5.0	4.5	4.0	3.5
	Cap	1.5	1.5	1.0	1.0
Tier 2 (Wind)	Target Price	3.5	3.5	3.5	3.5
	Cap	1.0	1.0	1.0	1.0
Tier 3 (Geothermal, Small Hydro, Digester	Target Price	3.0	3.0	3.0	3.0
	Cap	1.0	1.0	1.0	1.0

*For the purposes of this report, the Energy Commission has classified whole waste tire combustion as biomass.

Prospective new projects will bid for the amount of support they require. Bids will be based on the cents/kWh amount and the expected amount of generation. The lowest bids will receive support, subject to a 1.5 cents/kWh cap, with higher bids considered until funds are fully allocated. Winning projects will receive support for five years from their on-line date, but must be on-line prior to December 31, 2001.

Funds from the Emerging Technologies Account will be distributed to technologies or projects based on the outcome of multiple competitive Requests For Proposals (RFPs). The specific form of support for winning projects will be determined on a case-by-case basis. RFPs will be administered by the Energy Commission using criteria developed during the implementation period.

The consumer-side account includes funding for customer credits, consumer information and market-building activities. Of these two sub-accounts, only the customer credits require a fund distribution mechanism; these funds will be distributed through a simple per-kWh consumption credit. The credit will be paid out through certified providers (marketers, aggregators or suppliers who sell directly to end-use consumers), with the value determined by dividing available funds by the total kWhs of qualifying renewable power sales in each period, subject to a cap of 1.5 cents per kWh. Credits received must be reflected in consumer bills.

Implementation of the AB 1890 Report

The Commission's AB 1890 Report was approved by the Legislature, through enactment of Senate Bill (SB) 90, on October 12, 1997. SB 90 was developed to implement the provisions of the AB 1890 Report, with only minor modifications. Chief among these was language designating the Emerging Technologies funded by the provisions of AB 1890 to be photovoltaics, solar thermal, wind turbines of 10 KW or less, and fuel cells using renewable fuels.

Potential Near and Long-Term Effects on Renewable Energy Resources

As discussed further in Chapter IV, prior to industry restructuring, California's investor-owned electric utilities were required to develop new electricity resources through a regulatory process (associated with biennial proceedings to develop the Energy Commission's *Electricity Report*) that began with determining the need for new resources, based upon demand forecasts and supply options. This determination generally included a "set-aside" that reserved a portion of the "need" specifically for renewables. The amount of determined need, including the renewable set-asides, was to be allocated every two years to various projects and resource types through a competitive resource auction called the Biennial Resource Plan Update (BRPU).

Over the past few years, the approach to renewable resource set-asides in the BRPU proceedings has changed substantially, as the state has approached a more competitive, less regulated and planned energy supply market. Utility spending on public interest research and development decreased in preparation for competition. State-level resource planning and procurement auctions, including the portions set aside for renewable generation, were superseded by Federal Energy Regulatory Commission (FERC) rulings, and have been effectively discontinued. AB 1890 included specific public-interest funding support for continued research and development on renewable generating technologies and for transitional market support for existing, new, and emerging renewable resources.

While the advent of industry competition, and the rejection of the BRPU results by FERC, would probably have caused significant declines in California's diverse renewable resource base, the support provided by AB 1890 funding during the transition period has the near-term potential to keep the resource base relatively stable. More existing resources should become competitive, and more new renewable energy powerplants should be constructed. It is to be hoped that this effect will endure over the long term, as those renewable resources that can provide benefits to the state's air quality, and concurrently reduce CO_2 emissions, are proved to be increasingly cost-effective additions to the state's energy supply.

Changes in California's Transportation System

Since 1991, significant changes have also occurred in California's transportation policies that may affect global climate change emissions and strategies for reducing them. The following sections describe these changes and their implications in more detail.

Low Emission Vehicle Requirements

As discussed in more detail in Chapter VI of this report, expanded development and use of alternative, low-emission vehicles and fuels have the potential to greatly contribute to reductions in criteria air pollutants and CO_2. The California Air Resources Board (CARB) adopted Low-Emission Vehicle regulations in September, 1990,[7] to assist in meeting federal and California standards for carbon monoxide (CO), nitrous oxide (NOx), reactive organic gases (ROG) and ozone. The regulations established four new categories of emission standards for passenger cars and light-duty trucks: Transitional Low-Emission Vehicles (TLEVs); Low-Emission Vehicles (LEVs); Ultra-Low-Emission Vehicles (ULEVs); and Zero-Emission Vehicles (ZEVs) (which, at this time, are represented solely by all-electric vehicles). The regulations established a progressive fleet-average emission requirement, which manufacturers can meet by producing any combination of low-emission vehicles.

The initial regulations required the seven largest auto manufacturers to produce and offer zero-emission vehicles for sale in California in specific amounts, i.e., 2 percent of total sales, beginning with the 1998 model year; 5 percent in the 2001 model year; and 10 percent in the 2003 model year. While state and federal laws governing automotive emissions are similar, because of the state's severe air pollution problems, California has historically adopted more stringent standards than those contained in the Federal Clean Air Act. Similarly, California's LEV regulations, overall, are more stringent than the federal requirements, and there is no federal requirement for ZEVs.

Subsequent investigation of the feasibility of meeting the state's ZEV targets showed that battery technologies expected to be available by 1998 did not provide acceptable driving ranges (over 50 miles) for consumers. Following a series of public meetings and meetings with auto manufacturers during 1995, the CARB adopted the policy, in March, 1996, that the limitation on driving range would not allow ZEVs to be successfully marketed beginning in 1998. Advanced batteries that provide a 100 - 150-mile range, and have a longer lifetime, are expected to be produced by 2001; therefore, the Air Board amended the regulations to eliminate ZEV requirements for 1998 and 2002, without changing the requirements (10 percent) for the 2003 model year.

During its study of low-emission vehicles, CARB found that they could be cost-effective, based on estimates applying to the most cost-efficient manufacturers, with an incremental cost to the consumer of approximately $72.00. The incremental cost to consumers for TLEVs, EVs, and ULEVs, with regard to emissions, is estimated to be less than $1.00 per pound of emissions reduced.

Since March, 1996, significant progress has been made by auto manufacturers toward compliance with the LEV standards. As of the end of 1996, TLEVs comprised over 25 percent of 1996 model year vehicles, and more than 180,000 low-emission vehicles are expected to be for sale in California in 1997. Advanced batteries and fuel cell development are progressing well. It is apparent that the LEV market will be extremely competitive, and
that manufacturers will offer a variety of battery/vehicle combinations. Vehicles with ranges of 60 to 125 miles, and speeds up to 80 mph, are currently being produced by Honda, Toyota, Chrysler Dodge, and other manufacturers for 1997 or 1998 model cars and light trucks.[8]

Reformulated Gasoline Requirements

Reformulated gasoline was introduced in California in March, 1996, and is required to be used statewide. Before its introduction, the fuel industry and government agencies tested its performance, compatibility in gasoline-powered engines, and effects on fuel economy. Tests showed that reformulated gasoline (RFG) performs in vehicles as well as conventional gasoline, but reduces fuel economy. Fuel economy averages studied by a variety of institutions range from 1 - 3 percent (EPA)[9] to 2 - 3.5 percent (CARB, U. S. Department of Energy, respectively)[10] to 2 - 4 percent (Lawrence Livermore National Laboratory).[11] Reformulated gas has a lower energy content than conventional gasoline, due to the addition of oxygenates and reduced hydrocarbons in the fuel. Some fuel system problems were observed in tests of pre-1991 vehicles with high mileages (averaging 95,000 miles), but were comparable to the increasing rate of failure in fuel systems associated with vehicle aging observed in the control vehicles.[12]

Although a vehicle using reformulated gas consumes slightly more gasoline volume per mile, it is cleaner-burning than conventional gasoline, emitting about 15 percent less smog-forming pollutants per mile.[13] With regard to carbon dioxide emissions, California and national test data showed similar results, a slight decrease per gallon (0.6 percent - 1.1 percent) in CO_2 emissions from RFG, when compared to conventional gasoline.

The California Legislature has expressed concerns after receiving reports that methyl tertiary butal ether (MTBE), an additive in RFG, is showing up in ground and surface waters. The legislature is considering measures that would reduce or eliminate MTBE use in California. The University of California has been funded to summarize the available literature on health effects, and the Energy Commission to conduct a study of fuel supply implications of various options to phase out use of MTBE in California's reformulated gasoline.

Changes in Congestion and Transportation Demand Management Requirements

In the late 1980s and up to the mid-'90s, the California Legislature enacted numerous laws requiring regional governments to institute transportation regulatory and planning strategies directed toward reducing congestion and the demand for personal vehicle transportation. These laws were primarily targeted toward meeting federal and state standards for criteria air pollutants, but many would have concurrent CO_2-reduction benefits. Regional and local governments enacted rules and ordinances responding to these requirements and to local needs, including trip-reduction rules for employers, such as Regulation 15 (in the South Coast Air Basin) and Regulation 16 (in the San Francisco Bay Area).

Since the mid-'90s, many of these statutes have been modified to revise or expand the types of measures that can be used in trip reduction programs, or to effectively rescind previous regulations. For example, SB 772 (Hurtt, 1995) rescinded previous trip reduction requirements for the South Coast Air Quality Management District (SCAQMD). Rather than prescribing that employers implement a standard set of measures, such as van pooling and ridesharing programs, SCAQMD may now consider alternative methods to reduce air pollution, such as vehicle scrappage programs. Further, SB 382 (Lewis,1995), AB 2359 (Sher, 1994) and AB 2581 (Pringle, 1994), all narrow the scope of mandatory trip reduction measures, so that they are generally not applied to areas considered to be indirect emissions sources, such as theaters and shopping areas. Finally, SB 437 (Lewis,1995) prohibits air quality management districts, congestion management agencies and other public agencies from requiring an employer to implement an employee trip reduction program, unless the program is required by federal law and if its elimination will result in the imposition of legal sanctions on the local authority.

Congestion Management Programs have also lost ground. AB 2419 (Bowler), enacted in 1996, addresses the mandatory Congestion Management Programs enacted by state initiative in the early 1990’s. The law makes preparation of a Congestion Management Plan inapplicable where a majority of local governments in an urban county adopt resolutions to exempt themselves from that requirement.

Chapter VI of this report deals with transportation strategies for reducing CO_2 emissions in detail, and examines the potential effectiveness of transportation efficiency pricing measures; alternative-fuel, low emission vehicles; land use development alternatives; and transportation system management efforts designed to affect transportation demand.

Conclusions

The Energy Commission is committed to preserving and enhancing the benefits of California's environmental quality as the state transitions to a competitive electricity industry. Uncertainty precludes judging whether the effects on air emissions and other environmental impacts of restructuring the utility industry will be positive or negative as the market adjusts and responds to customers' choices. Since these results cannot be predicted at this time, the Energy Commission staff will continue to monitor the implementation of the deregulated electricity system and the responses of the existing regulatory framework, business, industry, the environmental community, institutions, and the public. These studies will require a cooperative effort among energy and environmental regulators, utilities, and the many stake-holders affected by the changes underway. New transportation policies and programs affecting California and the nation also need to be carefully monitored and evaluated for their potential impacts on greenhouse gas emissions, and strategies need to be developed to reduce both criteria air pollutants and carbon dioxide emissions from these sources.

To accomplish this objective, the Energy Commission should serve as a clearinghouse for data, and a source for electricity system computer simulation model development, and trend and data analysis, for all energy-economic sectors. As a critical part of this role, the Energy Commission staff should work closely with the Air Resources Board, the Departments of Forestry, Food and Agriculture, Water Resources, and Transportation, the Solid Waste Management Board, air districts, regional water boards and other regional and local government agencies to closely monitor and evaluate the unfolding events of utility restructuring and changes to California's transportation policies, and to recommend specific energy policies and strategies to reduce emissions that may contribute to global climate changes.

ENDNOTES

1. This report presumes that saving electricity will reduce greenhouse gas emissions. This assumption implies that future emissions per kW hour due to electricity generation are relatively constant. Potential changes in the mix of electricity generation resources, and their possible effects on emissions, are discussed elsewhere in this report.

2. Assembly Bill 1890, Article 7, 383.a., September 23, 1996.

3. Assembly Bill 1890, Article 7, 383.b, September 23, 1996.

4. California Energy Commission, *Policy Report on AB 1890 Renewables Funding*, P 500-97-002, March, 1997

5. The term "direct access market" is used in this report to refer to both physical direct access transactions and contracts for differences.

6. The Energy Commission proposed that market clearing prices be estimated based on monthly average utility short run avoided costs (SRAC), until such time as the CPUC determines that the power exchange price adequately represents market clearing prices. At that time the monthly average power exchange price will be utilized.

7. California Code of Regulations (CCR), Section 1960.1, Title 13, Low-Emission Vehicles.

8. Zochetti, Kate, "LEV Implementation Summary," CEC Staff Paper, December, 1996, p. 2

9. U. S. Environmental Protection Agency, Office of Mobile Sources, *Fuel Economy Impact Analysis of RFG*, August, 1995, p. 1.

10. EPA, Impact Analysis, p. 1.

11. Lawrence Livermore National Laboratory, *Assessment of California Reformulated Gasoline (RFG) Impact on Vehicle Fuel Economy*, January, 1997.

12. California Air Resources Board, "Cleaner Burning Gasoline Fact Sheet 6," August, 1996, p. 1.

13. California Air Resources Board, *CaRFG Performance and Compatibility Test Program, Executive Summary*, December, 1995, p. 3.

Chapter III

Greenhouse Gas (GHG) Emissions Inventory and Forecast: An Overview

Historical and Forecasted Emissions

This chapter presents a brief summary of the historical and forecasted GHG emissions inventories for California. The historical period covered includes 1990 through 1994, and the forecast covers the years 2000, 2005 and 2010. The year 1994 is used to illustrate the contribution of the different sub-sectors and fuels to California's total annual emissions. Emission estimates were primarily developed using standard methods approved at the national and international levels. In cases where information specific to California was available, however, different methods were used. The main Appendix to this report, *Historical and Forecasted GHG Emissions Inventories for California*, should be consulted for a more complete description of the assumptions and methods used, and for more detailed inventory data.

The Intergovernmental Panel on Climate Change (IPCC) has developed the concept of Global Warming Potential (GWP) to compare the radiative forcing effect of different gases relative to carbon dioxide. The GWPs used in this report are 21 and 310 for methane and nitrous oxide respectively. For definition, the GWP for carbon dioxide is one. Table III.1 presents a summary of the historical inventory of anthropogenic (originated from human activities) greenhouse gas emissions for California. All the emissions in this table are represented as carbon dioxide equivalents and were calculated by multiplying annual emissions, in thousands of tons, by their respective GWP.

As shown in Figure III.1, carbon dioxide emissions predominate, representing 87.7 percent of the total GHG emissions in 1994. Fossil fuel combustion produces the largest amount of CO_2 emissions, as shown in Table III.1. The remainder of carbon dioxide emissions, referred to as *Other* in Table III.1, are produced by the release of carbon dioxide during industrial transformation of raw materials, mainly in cement and lime kilns, and from limestone consumption.

Table III.1: California Greenhouse Gas Emissions
1990-1994

CO_2 Equivalent (thousand tons)					
	1990	1991	1992	1993	1994
Carbon Dioxide (CO_2)					
Fossil Fuel Combustion	389,270	373,104	374,499	365,558	383,143
Other	14,577	14,132	14,225	13,847	17,085
Subtotal	403,848	387,236	388,724	379,405	400,227
Methane (CH_4)					
Landfills	24,864	26,053	27,443	28,570	29,767
Agriculture	15,628	15,363	15,391	15,477	15,590
Oil and Gas Systems	2,647	2,676	2,651	2,639	2,621
Other	1,345	1,348	1,335	1,344	1,350
Subtotal	44,484	45,440	46,820	48,030	49,327
Nitrous Oxide (N_2O)					
Agriculture	3,187	3,065	3,129	3,121	3,454
Fuel Combustion	4,399	4,523	4,501	4,677	4,773
Industrial Processes	411	411	411	411	411
Subtotal	7,998	7,998	8,041	8,209	8,637
HFCs and PFCs*					
Total California Emissions	456,329	440,674	443,586	435,644	458,191
* There are two sources of HFCs and PFCs: primary aluminum smelting and HCFC-22 production. There is no primary aluminum smelting in California and the production of HCFC-22 could not be determined.					

Natural gas and motor gasoline each represent about 33 percent of all emissions from the combustion of fossil fuels, as can be seen in Figure III.2. Although natural gas represents a higher share (39 percent) of total energy from fossil fuel consumption in the state, its relatively-low carbon content results in much lower carbon dioxide emissions than gasoline, per unit of energy released during combustion.

Carbon dioxide emissions are presented by sector in Figure III.3. It is important to note that the Electricity Generation sector only includes emissions from power plants located in California, which is consistent with national and international conventions for inventorying emissions. The Electricity Generation sector includes both utility and non-utility generation. At the national level, this sector represents close to 40 percent of total carbon dioxide emissions from the combustion of fossil fuels, which is significantly higher than its 16.24 percent contribution in California. It is important to recognize, however, that slightly more carbon dioxide emissions are generated from out-of-state power plants serving California than from in-state power plants, even though more electricity is generated from in-state power plants. This is the result of the very small consumption of coal in California and heavy reliance on natural gas and, to some extent, renewable resources for electric power generation.

Figure III.1
Total Greenhouse Gas Emissions
Measured as CO_2 Equivalent: 1994

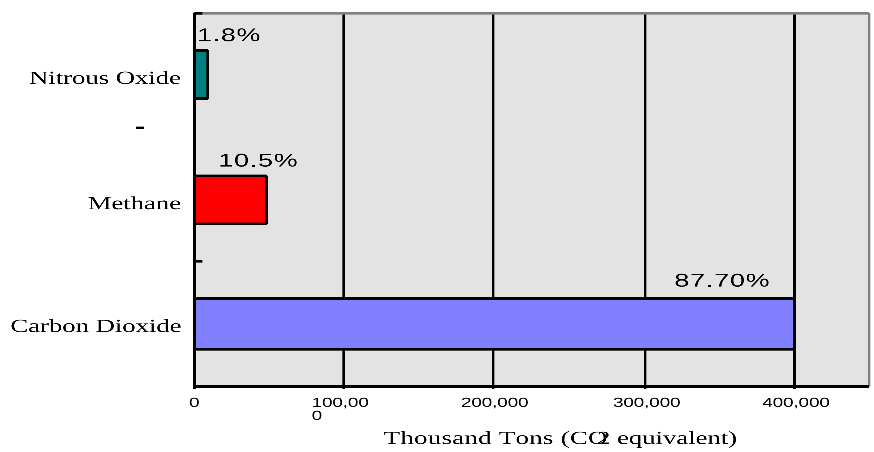
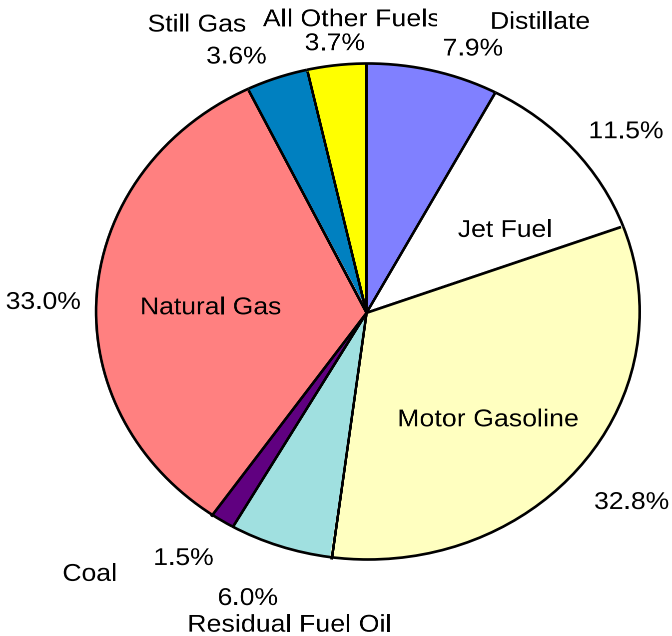
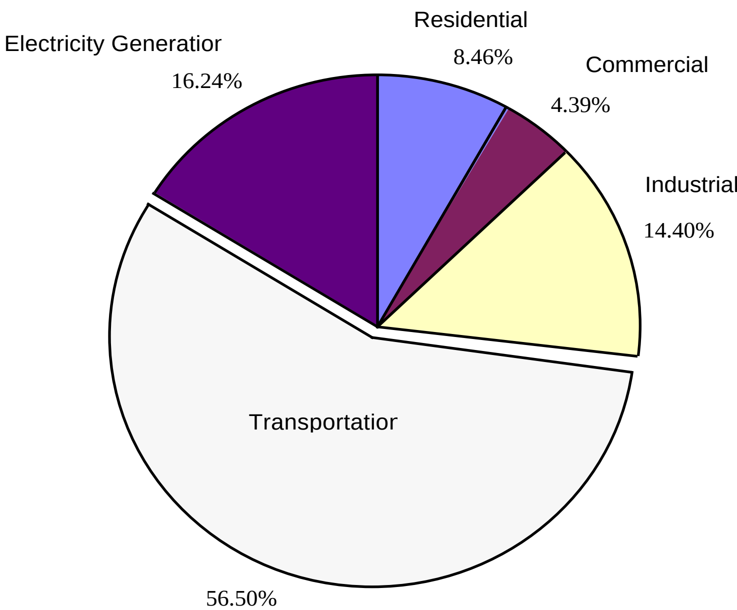


Figure III.2
Contribution of CO_2 Emissions from the Consumption of Fossil Fuels by Fuel Type: 1994



After carbon dioxide, methane is the most important greenhouse gas generated from anthropogenic activities. Methane emissions, in ascending order of importance, originate from the oil system (crude oil refineries, pipelines for oil and its products, and tankers), water treatment plants, fossil fuel combustion, the natural gas system, agriculture, and landfills. The last two sources represent more than 90 percent of all methane emissions. In landfills, methane is generated from the anaerobic (without or under low-oxygen conditions) bacterial decomposition of organic matter. Most of the emissions from the agricultural sector come from the digestive processes of domestic livestock and manure management activities.

Figure III.3
Carbon Dioxide Emissions from Fossil Fuel Consumption by Sector: 1994



Nitrous oxide (N_2O) emissions contribute only marginally to total state GHG emissions, as shown in Figure III.1. Most N_2O emissions originate from fossil fuel and wood combustion, and from the use of agricultural fertilizers.

Emissions in the future will depend on a number of factors, such as economic growth, structural changes in the economy, effectiveness of mandated energy efficiency standards, autonomous energy efficiency improvements, and fuel switching. Table III.2 presents a summary of the estimated emissions of greenhouse gases, measured as carbon dioxide, for the years 2000, 2005, and 2010. The forecasts shown in this table represent emissions based on a business-as-usual scenario, i.e., assuming that no measures are taken to decrease GHG emissions other than what would be achieved under existing programs. As expected, in 2010, more than 82 percent of the emissions would originate from the combustion of fossil fuels.

Methane would remain the second most important gas in California, contributing slightly more than 10 percent to total emissions. Nitrous oxide emissions would increase from 1.76 percent of 1990 emissions to slightly more than 2 percent. This increase in emissions is mainly the result of more vehicles utilizing catalytic converters, which have been shown to produce nitrous oxide.

Table III.2 Forecasted GHG Emissions: 2000, 2005, 2010 Carbon Dioxide Equivalent (Thousand Tons)					
	1990*	2000	2005	2010	Contribution in 2010 (%)
Carbon Dioxide					
Fossil Fuel Comb.	389,270	399,979	418,581	437,709	82.35
Ind. Processes	14,577	18,058	25,502	27,040	5.09
Methane	44,484	51,971	53,323	55,385	10.42
Nitrous Oxide	7,998	9,840	10,591	11,388	2.14
Total	456,329	479,849	507,996	531,523	100
* Historical baseline year					

The Climate Change Action Plan released by President Clinton in October, 1993, committed the United States to reducing greenhouse gas emissions to their 1990 levels by the year 2000. The historical inventory indicates that total GHG emissions in California by 1994 increased by only 0.58 percent from 1990 levels (see Table III.2). For the U.S., for the same period, the increase was close to 4 percent.[1] However, this slow increase in emissions may not continue, and an increase of about 4.8 percent with respect to the baseline year is expected by the year 2000. The minor decrease in carbon dioxide emissions from the combustion of fossil fuels through 1994 is the main factor in the observed slow increase in total GHG emissions. There is good reason to believe that most of this observed decrease was due both to the state of the economy[2] and to significant reductions in the use of residual fuel oil in marine vessels.[3] These conditions were temporary, and for this reason a significant increase in total emissions is expected by the year 2000 and beyond.

Electrical energy conservation programs in California have been successful in slowing the increasing demand for power production. This has resulted in lowering criteria pollutant emissions from power plants, which is expected to continue in the future. At the same time, emissions from in-state power plants are tightly controlled, contributing only about 4 percent to the total annual state NO_x inventory. For these reasons, electricity conservation programs, even though important, make only a small contribution to efforts to achieve compliance with ambient air quality standards for criteria pollutants. Such conservation programs are extremely important, however, in any serious effort to reduce emissions of greenhouse gases in the state, or the nation, and have also been found to be one of the most cost-effective emissions reduction strategies, with respect to carbon dioxide.[4]

The importance of energy conservation programs in reducing CO_2 emissions is clear when it is considered that, in 1994, about 16 percent of these emissions from the combustion of fossil fuels in California originated from burning fossil fuels in power plants. Out-of-state power plants serving California emit even more carbon dioxide emissions than in-state plants. Since it is irrelevant where carbon dioxide emissions occur, from a global climate change perspective, electricity conservation programs in California play an extremely important role in reducing carbon dioxide emissions from both in-state and out-of-state power plants.

The U.S. EPA adopted new, more stringent national ambient air quality standards for ozone and particulate matter in July, 1997. The agency is also developing general guidelines on how to develop comprehensive air quality management plans that take into consideration the relationships between both types of pollutants. A similar approach was taken by the South Coast Air Quality Management District in developing their 1997 PM10 Air Quality Management Plan. Studies at the regional and national levels seem to indicate that reduction in CO_2 emissions may also result in significant sustainable reductions in the emissions of several criteria pollutants. For these reasons, it seems advisable to start an exploratory quantitative analysis in California on cost effective options to reduce both greenhouse gases and criteria pollutants in an integrated fashion.

Non-Greenhouse Gas Emissions Contributing to GCC

The California emissions inventory of Non-Greenhouse Gases (known as "criteria pollutants" and associated with health-based air quality standards) is maintained by the California Air Resources Board (CARB). Tables III.3**,** III.4,and III.5 show CARB's projections of inventories of nitrogen oxides (NO_x), reactive organic gases (ROG), and carbon monoxide (CO).[5] The 1995, 2000, 2005 and 2010 projections are based on 1993 data.

Man-made emissions of carbon monoxide, nitrogen oxides, and reactive organic gases are all primarily produced by the burning of fossil fuels in industry and transportation; additional CO is produced by the combustion of biomass in natural forest fires and human forest clearing and agricultural processes. As discussed in Chapter I, these criteria pollutants, while not considered directly-emitted greenhouse gases, are precursors to compounds associated with global climate change, e.g., CO elevates concentrations of methane and tropospheric ozone, and eventually oxidizes to form CO_2. NO_x and ROG are also precursors to ground level ozone, also a GHG. The CO_2 inventory calculations assume a small fraction of oxidized carbon as CO. The downward trend in these ozone precursors, as shown in Tables III.3 and III.4, would suggest ozone levels will decrease somewhat throughout the state over the forecast period. The values shown in Table III.5 confirm that CO emissions show a downward trend down for the forecast period.

Table III.3
California Reactive Organic Gases (ROG) Emissions Forecast (kTons/year)

Mobile Sources	**1993** [a]	**1995**	**2000**	**2005**	**2010**
On Road Vehicle					
Light Duty Passenger	383	366	228	150	93
Light and Medium Duty Trucks	212	195	113	70	44
Heavy Duty Gas Trucks	14	13	7	6	4
Heavy Duty Diesel Trucks	24	22	15	13	13
Motorcycles	4	4	3	4	4
Heavy Duty Diesel Urban Buses	1	1	1	1	1
Other Mobile					
Off Road Vehicles	56	59	59	64	71
Trains	2	2	2	2	2
Ships	2	2	2	2	2
Aircraft (Government)	9	8	8	8	8
Aircraft (other)	10	10	11	12	13
Mobile Equipment	33	31	32	34	35
Utility Equipment	20	27	14	10	6
TOTAL MOBILE SOURCES	770	738	494	376	298
Stationary Sources					
Fuel Combustion	31	31	33	36	39
Waste Burning	21	22	30	31	32
Solvent Use	292	297	300	320	351
Petroleum Process, Storage & Transfer	100	83	73	75	76
Industrial Processes	18	18	21	23	26
Misc. Processes	154	153	151	151	154
Misc.	7	7	8	9	9
TOTAL STATIONARY SOURCES	623	611	616	644	687
TOTAL CALIFORNIA	1,393	1,349	1,110	1,020	985

a. Base year

Table III.4
California Nitrogen Oxides (NO_x) Emissions Forecast (kTons/year)

Mobile Sources	**1993** [a]	**1995**	**2000**	**2005**	**2010**
On Road Vehicle					
Light Duty Passenger	312	294	198	147	116
Light and Medium Duty Trucks	234	226	161	128	107
Heavy Duty Gas Trucks	53	52	40	34	28
Heavy Duty Diesel Trucks	184	175	156	143	144
Motorcycles	2	2	2	2	2
Heavy Duty Diesel Urban Buses	6	6	6	6	5
Other Mobile					
Off Road Vehicles	12	12	13	14	15
Trains	55	54	53	53	53
Ships	21	19	20	21	23
Aircraft (Government)	6	5	5	5	5
Aircraft (other)	10	11	13	14	15
Mobile Equipment	149	149	139	120	115
Utility Equipment	1	1	2	2	1
TOTAL MOBILE SOURCES	1,043	1,006	806	687	629
Stationary Sources					
Fuel Combustion	232	223	195	194	207
Waste Burning	4	4	5	5	5
Solvent Use	0	0	0	0	0
Petroleum Process, Storage & Transfer	5	5	5	5	5
Industrial Processes	27	31	31	34	38
Misc. Processes	3	3	3	3	3
Misc.	6	5	4	4	4
TOTAL STATIONARY SOURCES	277	270	242	245	262
TOTAL CALIFORNIA	1,320	1,276	1,048	932	891

a. Base year

Table III.5
California Carbon Monoxide (CO) Emissions Forecast (kTons/year)

Mobile Sources	**1993 [a]**	**1995**	**2000**	**2005**	**2010**
On Road Vehicle					
Light Duty Passenger	3,642	3,426	2,069	1,506	1,128
Light and Medium Duty Trucks	2,041	1,882	1,191	824	685
Heavy Duty Gas Trucks	246	205	113	95	87
Heavy Duty Diesel Trucks	107	106	111	125	142
Motorcycles	17	17	16	18	20
Heavy Duty Diesel Urban Buses	1	1	1	1	1
Other Mobile					
Off Road Vehicles	269	282	270	302	336
Trains	8	8	8	8	8
Ships	3	2	2	3	3
Aircraft (Government)	29	21	21	21	21
Aircraft (other)	84	81	83	90	96
Mobile Equipment	583	604	592	627	655
Utility Equipment	148	199	126	94	53
TOTAL MOBILE SOURCES	7,177	6,833	4,602	3,713	3,235
Stationary Sources					
Fuel Combustion	393	404	420	469	506
Waste Burning	360	384	499	527	560
Solvent Use	0	0	0	0	0
Petroleum Process, Storage & Transfer	3	3	3	3	3
Industrial Processes	16	17	18	19	21
Misc. Processes	97	97	98	98	99
Misc.	8	8	8	9	9
TOTAL STATIONARY SOURCES	876	913	1,046	1,125	1,197
TOTAL CALIFORNIA	8,053	7,746	5,648	4,838	4,432

a. Base year

ENDNOTES

1. Energy Information Administration, *Emissions of Greenhouse Gases in the United States,1995*, October 1996. Table ES2. In keeping with the EIA's approach, this document for California includes emissions from the consumption of "international bunker fuels" in the U.S. national inventory.

2. The real Gross State Produce (GSP) was at its lowest point in 1993, for the period 1990-1994, as shown in the publication *New Estimates for 1993-1994 and Revised Estimates for 1977-92*, Bureau of Economic Analysis, Regional Economic Analysis Division, U.S. Department of Commerce, June, 1997.

3. The significant drop in the sales of residual fuel oil to marine vessels was the result of the adoption of a tax in 1991 that was repealed in January, 1993.

4. Krause, Florentine, Oliver, D. and Koomey, J., *Negawatt Power: The Cost and Potential of Electrical Efficiency in Western Europe: Energy Policy in the Greenhouse. Volume II, Part 3B*, International Project for Sustainable Energy Paths, 1995.

5. Mr. Dennis Goodenow, Manager, Emission Inventory Systems Section, CARB, to Mr. Matthew Layton, Air Quality Unit, CEC, Letter, dated May 28, 1997

Chapter IV__________________________

Reducing CO_2 Emissions from Energy Generation and Use

Introduction

Through its energy efficiency policies and programs, high reliance on natural gas generation, and the development of renewable resource technologies over the past two decades, California has made substantial inroads into decreasing CO_2 emissions from electricity generation and use in the residential, commercial, and industrial sectors. This chapter describes and evaluates the main strategies in place in the state, California's approach to evaluating environmental damages (including CO_2 emissions) from electricity generation, and conclusions reached. Possible CO_2 emissions reduction results with various levels of funding for energy efficiency measures for the residential and commercial sectors, development of renewable energy resources, and continued development and use of high-efficiency gas generation technologies are also presented. Scenarios presented for the residential and commercial sectors, and for high-efficiency gas generation technologies, show associated potential reductions in CO_2 emissions.

Given the voluntary nature of current Industrial Sector energy efficiency programs, no cost/benefit analyses of these programs for reducing emissions have, as yet, been possible. Although funding levels for development of renewable energy resources over the next four years proposed in the Commission's *1997 (AB 1890) Renewables Report,*have been approved by the Legislature, an in-depth analysis of the CO_2 emissions reduction effects of these funding levels has not been attempted in this report. Further, as described in Chapter II, recent deregulation of California's electric utility industry presents many uncertainties, both with regard to projecting future levels of energy efficiency and renewable resources development and integration into the electricity system. The Energy Commission anticipates further analyses, over the next few years, of the effects on GHG emissions of increased energy-efficiency in the residential, commercial, and industrial sectors, additional use of natural gas, and development of renewable energy resources.

IV.1. Residential and Commercial Emissions Reduction Strategies

In the *1991 Global Climate Change Report*, anticipated energy savings from utility-managed energy efficiency programs over the next decade were one of the major sources for a forecast of reduced CO_2 emissions in the residential and commercial sectors. This section provides estimates of the probable reductions of CO_2 emissions and energy savings resulting from different levels of funding of publicly-financed electricity and natural gas efficiency programs from 1995 to 2010. Energy efficiency investments can provide the same or higher levels of energy services (such as space heating, lighting, or process tasks), while using less energy. Most investments in energy efficiency are cost effective on their own, without considering any economic value for reducing criteria air emissions. That is, the present value of the annual dollar savings on electricity or gas bills will exceed the initial cost of the conservation measure before the end of the measure's useful life, which averages 5 or 10 years. Thus, the CO_2 reductions analyzed here are a "free good," or spillover, effect from energy efficiency investments, because they are economical, independently of any value in reducing CO_2 emissions.

This section treats future energy efficiency programs as measures to reduce CO_2 emissions and describes, as scenarios, different levels of savings that might occur depending on the effectiveness and overall funding allocated to the programs. Scenario work is also related to earlier forecasts of savings from these programs in the earlier Energy Commission report in 1991. As compared to 1991, in 1997 a lower level of near-term energy savings from these programs is anticipated, because funding reductions have occurred over the last few years due to impending utility restructuring. In part, changes in the business objectives of electric utilities have brought about these reductions and, in part, they have resulted from financial pressure on utilities to collect sufficient revenues to retire their stranded generation assets. In 1996, legislation was passed in California to partially mitigate the utilities' conflict between trying to increase revenues and funding energy saving programs. AB 1890 requires electric utilities to fund energy efficiency programs at specified minimum levels from 1999 to 2002. The funding of energy efficiency programs before 1999 and after 2002 is uncertain.

A recent California Public Utilities Commission (CPUC) decision created an independent board to coordinate the statewide development of new, publicly-funded energy efficiency programs from 1998 to 2002. The decision also requires that these programs ultimately privatize the provision of cost-effective energy efficiency services, so that customers seek and obtain them in the private, competitive market. AB 1890 and recent CPUC decisions have removed some of the uncertainty of whether funding for energy efficiency programs would continue beyond 1997, how their orientation will change, and which entities will manage the new programs.

The goal of market transformation programs is to achieve sustainable changes in market structure and behavior that will allow future energy savings to be achieved by private market firms, rather than through publicly-funded programs. Anticipated energy savings from the new "market transformation" type of future programs are speculative, however. Indeed, estimates of energy savings or load impacts of existing market transformation program designs are few, and the industry presently is discussing how to best measure market transformation. In the next section, the use of scenarios to deal with this uncertainty with respect to future energy savings is explained.

To be consistent with the most current emissions inventory carried out by the Energy Commission (see Appendix A), this chapter uses the Energy Commission's previously adopted 1994 forecasts of electricity and natural gas use as the Base Case for all projections of energy savings and resulting CO_2 emissions reductions. Baseline CO_2 emissions from the residential and commercial sectors represent about two-thirds of the total CO_2 emitted by the production of electrical energy in California.[1]

Energy Efficiency Program Scenarios

This section presents three scenarios of future energy savings impacts from efficiency programs, and the resulting changes in CO_2 emissions. The scenarios attempt to capture the range of uncertainties that exist in any forecast of program effects in the rapidly-changing regulatory environment. The three scenarios for the funding of energy efficiency programs are: 1) 1994 Constant Funding; 2) 1996 Constant Funding; and, 3) Declining Funding After 2002 ("Decline After 2002"). The time period covered for each scenario is from 1994 to 2010. Key years used to report savings are 2000, 2005 and 2010. The following describes how the scenarios were used to characterize the effects of efficiency programs on CO_2 emissions by reducing electrical and natural gas demand. Electricity savings under the three scenarios are described first.

Electricity Savings Based on Scenarios

The first scenario, 1994 Constant Funding, presents the forecast of electricity savings by residential and commercial customers that was developed as part of the Energy Commission's 1994 Electricity Report process, and serves as a reference for the other scenarios. This scenario assumes generally constant funding of roughly $230 million per year for these programs from 1996 to 2005. It shows the level of savings expected when activity in energy efficiency programs was at an all time high.[2] Two more-recently developed scenarios, the 1996 Constant Funding Scenario and the Decline After 2002 Scenario, include effects of the 39 percent drop in funding for electricity efficiency programs that occurred between 1994 and 1996 as well as the spending requirements of AB1890 for 1999 to 2002.[3] The 1996 Constant Funding Scenario[4] presumes that public authorities will continue to fund the programs for commercial and residential customers at roughly the same funding levels being spent today ($189 million for electricity and $60 million for gas).[5] Implicitly, this scenario assumes that the initial energy savings impacts of the energy efficiency programs after 2002 will be at the same level of savings that was achieved by programs operated between 1996 and 2001.

The 1996 Constant Funding Scenario assumes that traditional energy efficiency program designs are replaced by an increased emphasis on programs that achieve market transformation objectives. It is assumed that all future market transformation programs focus on the reduction or elimination of market barriers and result in significantly more long term energy savings compared to traditional historical programs. As a result, more energy savings per dollar of expenditure are achieved in this scenario because the model captures the spillover of energy savings from program participants to non-participants over time.

The Decline After 2002 Scenario projects the emissions reductions that would occur if public funding for these programs were terminated after 2002.[6] This scenario does not presume that programs will have market transformation effects.

The emissions reductions associated with natural gas demand in the residential and commercial customer sectors is quite small compared to the potential reduction in CO_2 emissions associated with electrical demand. The ER 94 process did not include a forecast of savings from future gas efficiency programs. Thus there is no "1994 Constant Funding" scenario for natural gas programs. However, the staff used the *1995 Natural Gas Market Outlook*[7] as the basis for its estimates of the natural gas demand from 1995 to 2010. For the 1996 Constant Funding Scenario and Decline After 2000 Scenarios, the staff assumed that a non-bypassable surcharge for all natural gas users will be adopted by the Legislature in 1997 (similar to the one adopted for electricity users in 1996) and that natural gas market transformation-type programs will begin in January 1998 for the 1996 Constant

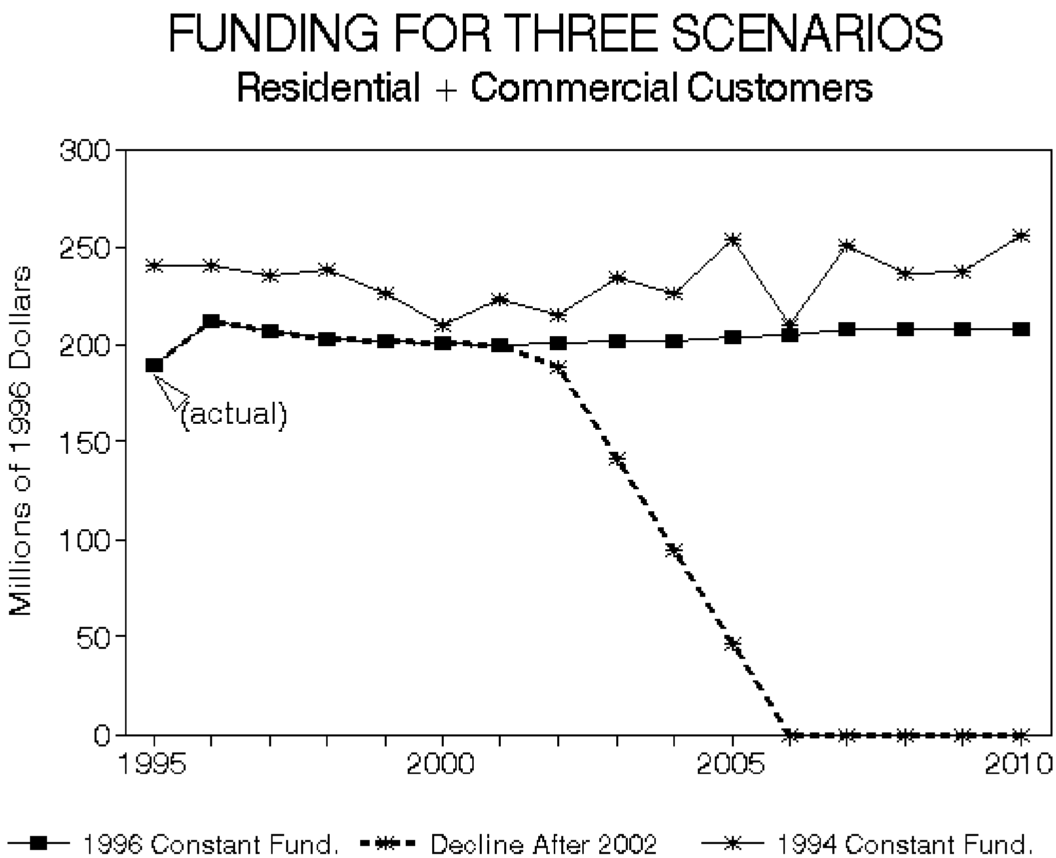
Funding Scenario. Staff patterned its forecast of savings and emission reductions due to gas efficiency programs on trends in the Decline After 2002 Scenario and 1996 Constant Funding Scenario for electricity.

The model for the 1994 Constant Funding Scenario was developed in 1994 using methods and models that traditionally furnish resource forecasts for the Commission's Electricity Report process.[8] The Commission ultimately adopted forecasts of electricity use that included staff's recommended modifications to utility forecasts of energy savings from their programs. For the other two scenarios, two new models were used in 1996 to independently estimate the potential energy savings that might occur. In brief, the first model, DSM Energy Resource Assessment Methodology (DENRAM) estimated total load impacts in energy savings and CO_2 emissions, while the California DSM Resource Assessment Model (CALRAM) identified technologies and end uses that would be likely to save the most energy.[9]

The remainder of this section has two parts: expected CO_2 emissions from different levels of electricity efficiency programs; and CO_2 emissions from different levels of natural gas efficiency programs.

CO_2 Emissions: Three Electricity Efficiency Program Scenarios

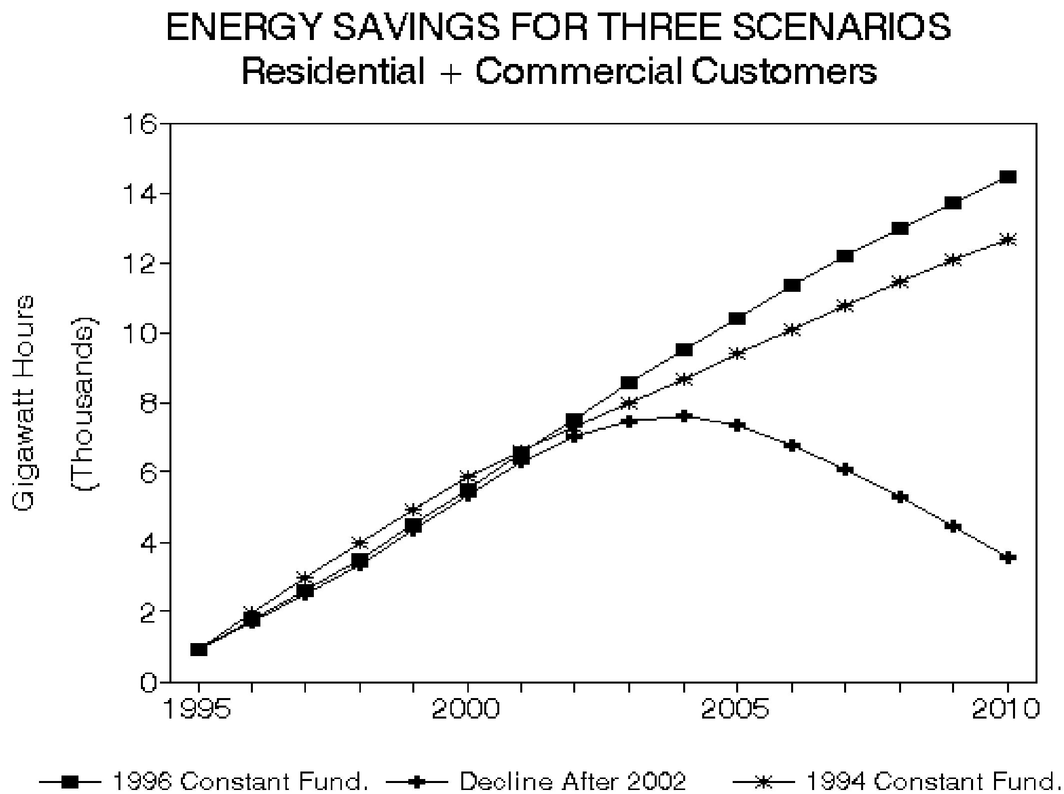
Figure IV.1-1 shows the funding assumptions for the three scenarios regarding electricity efficiency programs. The variability of funds in the 1994 Constant Funding scenario reflects the changes in "total cost" for the programs that was provided as part of ER 94.[10] Note that the other



two scenarios included the "actual" expenditures for 1995.[11] Figure IV.1-2 shows the savings in electrical energy represented by each of the three scenarios for the years 1995 through 2010.

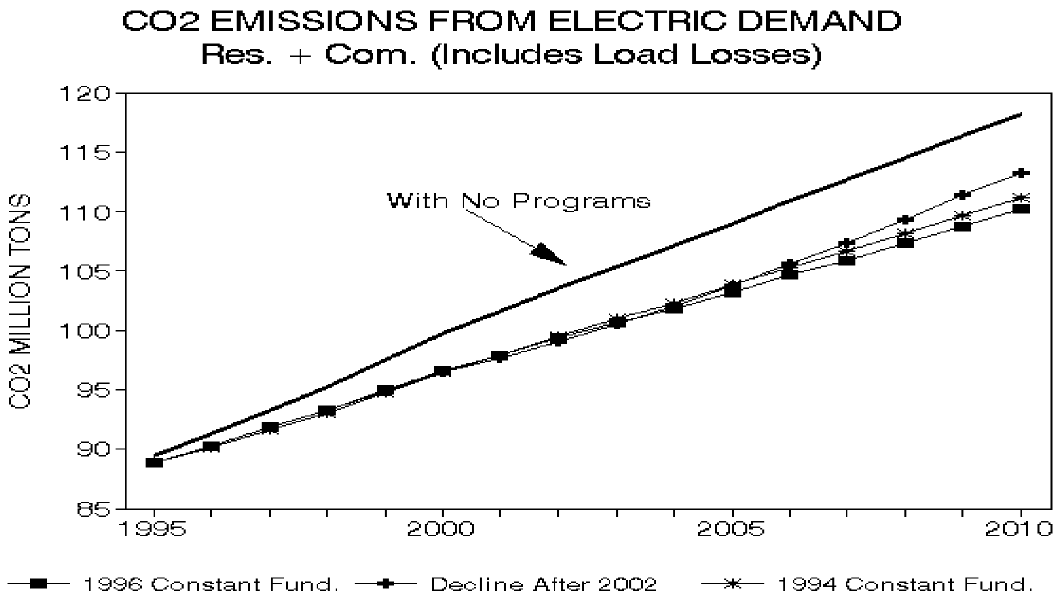
Differences in funding levels and program effectiveness determine most of the difference in energy savings between scenarios. Because of higher funding between the years 1995 and 1997, the savings from the 1994 Constant Funding Scenario initially exceeded savings from the other two scenarios. However, the savings from the 1996 Constant Funding Scenario exceed those from the first scenario beginning in 2001. The projected spillover effects from the 1996 Constant Funding Scenario exceeded the effect of the overall lower program funding.

Staff converted electricity savings to tons of CO_2 reduction by using the conversion figure of



300,000 pounds of carbon per GWh saved.[12] This conversion rate may be low (conservative), perhaps by as much as 50 percent,[13] but it reflects California's generation resource mix, which does not rely heavily on high carbon-content fuels such as coal. Staff converted the weight of carbon to equivalent weight of CO_2 by multiplying the carbon's weight by a factor of 3.7.[14]

The emissions of CO_2 under each scenario for the years 1995 to 2010 is shown in Figure IV.1-3. The emissions include the effects of "load losses" caused by the reduced energy required for electrical transmission and distribution. The figure also includes, for reference, the emissions that would result if no new efficiency programs were offered during the period ("With No Programs").



From 2000 to 2005, the "1994 Forecast" produces slightly higher levels of CO_2 emissions than the other two scenarios. When that forecast was being reviewed late in 1994, many analysts believed it was overstating the amount of electricity savings that could be achieved from energy efficiency programs over 20 years. This belief that energy efficiency programs were going the way of the dinosaurs followed announcements by investor-owned utilities in 1994 that they were intending to significantly reduce current and future funding for energy efficiency programs. The lower emissions forecast by the 1996 Constant Funding and Decline After 2002 scenarios reflects the funding requirements for efficiency programs mandated by AB 1890, which were higher than anticipated by many observers in 1994. From 2005 to 2010 the termination of energy efficiency programs under the "Decline After 2002" scenario is represented by the increase of CO_2 emissions to levels above those of the other two scenarios.

Table IV.1-1 summarizes the emissions of CO_2 for each scenario for 3 years: 2000, 2005 and 2010. The scenarios are listed in order of increasing emissions in 2010. The table also shows the emissions estimated if no efficiency programs were established ("No Programs").

Table IV.1-1
CO_2 Emissions due to Electricity Demand by Residential and Commercial Customers
(Millions of Tons)

SCENARIO	2000	2005	2010
1996 Constant Funding	96	103	110
1994 Constant Funding	96	104	111
Decline After 2002	96	104	113
(No Programs)	100	109	118

Certain energy saving technologies will be promoted by the energy efficiency programs. Table IV.1-2a shows the major technologies that are expected to reduce electricity demand in the residential and commercial customer classes over the next decade. Refrigeration, lighting and heating, ventilation and air conditioning (HVAC) measures were cited in these utility reports as sources of most of the energy savings in the residential and commercial customer classes.[15]

Table IV.1-2a
Principal Measures in Electricity Efficiency Programs of Investor Owned Utilities

Customer	Measure or Group of Measures	PGE [16]	SCE	SDGE
Residential	Refrigerator Recycling		x	
	Compact Fluorescent		x	x
	Evaporative Cooler		x	
	High Efficiency Air Conditioner		x	
	High Efficiency Refrigerator		x	x
	Trees		x	
	Weatherstripping			x
	Wall or Attic Insulation			x
Commercial	Customized HVAC EMS (Audits)	x		
	Customized Refrigeration EMS (Audit)	x	x	
	Customized Interior Lighting (Audits)		x	x
	Customized Process Heat Applications	x	x	
	HVAC Controls	x	x	
	Chiller Controls/ Optimizers	x		
	HVAC Adjustable Speed Drive	x		
	Efficient Water Chiller	x		x
	Window Films	x		
	HID Exterior Lighting	x		
	Compact Fluorescent Light		x	x
	Thermal Oxidizer			x

The list of technologies below (Table IV.2-b) represents the most promising energy efficiency measures for each end use over the next decade. The list was compiled from CALRAM, which relied on program participation data provided by PG&E, and SDG&E in 1995, and by SCE in 1994.

Table IV.2-b

Residential Customers

Clothes Dryer

_ Efficient Electric Dryer -- 966 kWh/year
_ Heat Pump Dryer with Electrical Consumption of 293 kWh/year
_ Microwave Dryer with Electrical Consumption of 617 kWh/year

Hot Water & Clothes Washers

_ Efficient Clothes Washer
_ Horizonal Axis Clotheswasher

Refrigerator & Refrigerator/Freezers

_ Efficient Refrigerator/Freezer Combinations with 10, 15, 20, 25, or 30 percent less energy use than specified in the 1993 Appliance Standards (five technologies)
_ Super Efficient Refrigerator/Freezer with 40 percent less energy use than specified in the 1993 Appliance Standards

Central Air Conditioning

_ Efficient Heat Pump with the following rating: Heating Seasonal Performance Factor (HSPF) of 7.5/Seasonal Energy Efficiency Ratio (SEER) of 11

Room Air Conditioners

_ Efficient Room Air Conditioners with Energy Efficiency Ratio (EER) of 10 or EER of 12 (two technologies)
_ Window Heat Pump with the Coefficient of Performance (COP)=3.2

Exterior Lights & Pool Pumps

_ Two Speed Pool Pump - (2 HP size)

Evaporative Space Cooling

_ Evaporative Cooler- 5,000 CFM

Freezers

_ Efficient Freezers, Upright Manual Defrost with 10% or 20% less energy use than specified in the 1993 Appliance Standards (two technologies)

Interior Lighting

_ Four-Foot Long 2-lamp Lighting Fixtures with T-8 Lamps, Electronic Ballast, Reflectors

Commercial Customers

Heating, Ventilation, Air Conditioning

_ Efficient Water Source Heat Pump
_ High Efficiency Room Heat Pump with rating of: Heating Coefficient of Performance (HCOP) 2.7 or Cooling Coefficient of Performance (CCOP) 2.5
_ Hydronic Heat Pump Variable Flow Valve
_ New Glazing -- High Performance Tint or Tinted two technologies)
_ Reducing Over-ventilation
_ Variable Speed Drive Cooling Tower Fans
_ Variable Speed Drive Hot and Chilled Water Loop Pump

Space Cooling

_ Chilled Water Reset Controls to ImproveChiller performance
_ Chiller Optimizer to Optimize the Sequencing of Multiple Chillers
_ Chiller Strainer Cycle in Cooling Tower Piping Arrangement
_ Cooling Tower Installation-Packaged System

_ Cooling Tower Propeller Fans
_ Double Pane Low Coated Glazing
_ Economizer Installation -- Central System
_ Economizer Installation -- Packaged System
_ Economizer Maintenance
_ Evaporate Cooling -- Indirect -- Central System
_ Gas Absorption Chiller
_ High Efficiency Centrifugal Chiller
_ High Efficiency Direct Expansion A/Cs with Coefficient of Performance (COP) of 2.9 or with COP of 3.2 (two technologies)
_ High Efficiency Reciprocating Chillers
_ Two-Speed Cooling Tower Fans
_ Variable Speed Drive Centrifugal Chiller

Refrigeration

_ Anti-Condensate Heater Controls for Reach-in Display Cases
_ Electric Defrost Demand Control for Refrigeration Systems
_ High Efficiency Compressors
_ Hot Gas Defrost to Defrost the Refrigeration System Compressor
_ Low Head Pressure -- Floating Head (i.e., Allow Refrigeration System Head Pressure to Float When Ambient Temperature is Low)
_ Oversized Evaporative Condenser with Temperature Difference (TD) of 15 degrees F.
_ Water Cooled Condensers

Interior Lighting

_ Indoor Lighting-- High, Medium, or Low Load Reduction Systems (three technologies)
_ Occupancy Sensor Pack to Control Lighting-200 Square Feet

Other End Uses

_ Infra Red Fryer-Stainless Steel (Cooking)
_ Point of Use Water Heating (Hot Water)

The previous section of this chapter has presented the likely impacts of three different levels of funding for energy efficiency programs on CO_2 emissions due to electricity demand in the commercial and residential sectors. It has also identified technologies that could contribute to future savings in electricity and reduction in CO_2 emissions. The section estimates the effects of two scenarios (Decline after 2000 and 1996 Constant Funding) on the emissions of CO_2 due to the effects on natural gas use of implementing energy efficiency programs at the end use level or onsite.

CO_2 Emissions: Two Natural Gas Efficiency Program Scenarios

The method used to determine reductions in electricity demand due to new efficiency programs was based on methods that the staff used as part of the ER 96 process; however, the staff did not previously develop a similar forecast of program savings for natural gas. For the purposes of this report, the staff has estimated natural gas savings by developing two scenarios for the programs and then estimating the energy and CO_2 emissions reductions associated with these scenarios, using DENRAM.   These savings estimates were not part of the Commission's ER 96 process; they are presented in this report to help estimate CO_2 emissions only.

In 1995, California's gas utilities' new residential and commercial energy efficiency programs generated annual energy savings of 23.42 million therms (approximately 0.5 percent of demand).[17] The 1996 Constant Funding Scenario presumes that the annual incremental savings for each year from 1996 to 2015 will be the same: 23.42 million therms. The Decline after 2002 Scenario presumes that the annual incremental savings will continue at 23.42 million therms from 1996 to 2001, but then will drop from 23.42 million therms in 2002 to 0 therms by 2006 and continue at 0 therms through 2010. Program effects were presumed to have a 6 year lifetime. The cumulative savings over time flowing from each annual incremental saving was patterned using the same persistence curves used to calculate the persistence of electricity program effects.[18]

Table IV.1-3 shows the estimated uncommitted gas savings in millions of therms for the 1996 Constant Funding Scenario. Each column shows the annual incremental savings (23.42 million therms) and the amount of savings that continues from the initial savings year (e.g., 1995) to 2010.

Table IV.1-3
Millions of Therms Saved: 1996 Constant Funding Scenario

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
1995	23.4	22.9	22.3	21.2	19.1	15.9	11.7	7.5	4.3	2.2	1.1	0.5	0.3	0.0	0.0	0.0
1996		23.4	22.9	22.3	21.2	19.1	15.9	11.7	7.5	4.3	2.2	1.1	0.5	0.3	0.0	0.0
1997			23.4	30.2	30.2	29.4	27.3	23.2	17.6	11.5	6.7	3.6	1.8	0.9	0.4	0.5
1998				23.4	30.2	30.2	29.4	27.3	23.2	17.6	11.5	6.7	3.6	1.8	0.9	0.4
1999					23.4	30.2	30.2	29.4	27.3	23.2	17.6	11.5	6.7	3.6	1.8	0.9
2000						23.4	30.2	30.2	29.4	27.3	23.2	17.6	11.5	6.7	3.6	1.8
2001							23.4	30.2	30.2	29.4	27.3	23.2	17.6	11.5	6.7	3.6
2002								23.4	30.2	30.2	29.4	27.3	23.2	17.6	11.5	6.7
2003									23.4	30.2	30.2	29.4	27.3	23.2	17.6	11.5
2004										23.4	30.2	30.2	29.4	27.3	23.2	17.6
2005											23.4	30.2	30.2	29.4	27.3	23.2
2006												23.4	30.2	30.2	29.4	27.3
2007													23.4	30.2	30.2	29.4
2008														23.4	30.2	30.2
2009															23.4	30.2
2010																23.4
Total	23.4	46.3	68.6	97.1	124.1	148.2	168.1	182.9	193.0	199.3	202.9	204.8	205.7	206.1	206.3	206.7

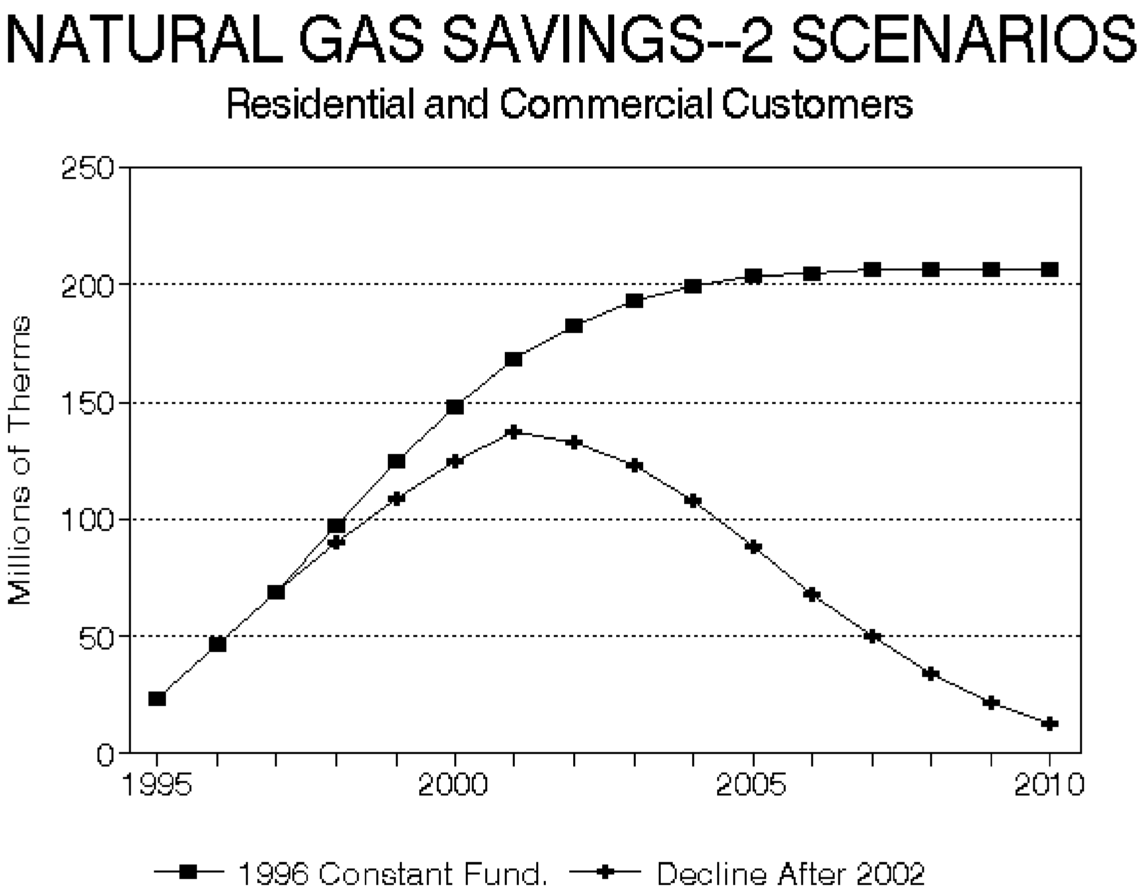
The table below (Table IV.1-4) shows the savings in millions of therms for the Decline After 2002 Scenario.

Table IV.1- 4
Millions of Therms Saved: Decline after 2002 Scenario

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
1995	23.4	22.9	22.3	21.2	19.1	15.9	11.7	7.5	4.3	2.2	1.1	0.5	0.3	0.0	0.0	0.0
1996		23.4	22.9	22.3	21.2	19.1	15.9	11.7	7.5	4.3	2.2	1.1	0.5	0.3	0.0	0.0
1997			23.4	22.9	22.3	21.2	19.1	15.9	11.7	7.5	4.3	2.2	1.1	0.5	0.3	0.0
1998				23.4	22.9	22.3	21.2	19.1	15.9	11.7	7.5	4.3	2.2	1.1	0.5	0.3
1999					23.4	22.9	22.3	21.2	19.1	15.9	11.7	7.5	4.3	2.2	1.1	0.5
2000						23.4	22.9	22.3	21.2	19.1	15.9	11.7	7.5	4.3	2.2	1.1
2001							23.4	22.9	22.3	21.2	19.1	15.9	11.7	7.5	4.3	2.2
2002								11.7	15.1	15.1	14.7	13.6	11.6	8.8	5.8	3.4
2003									5.9	7.5	7.5	7.4	6.8	5.8	4.4	2.9
2004										2.9	3.8	3.8	3.7	3.4	2.9	2.2
2005											0.0	0.0	0.0	0.0	0.0	0.0
2006												0.0	0.0	0.0	0.0	0.0
2007													0.0	0.0	0.0	0.0
2008														0.0	0.0	0.0
2009															0.0	0.0
2010																0.0
TOTL	23.4	46.3	68.6	89.7	108.9	124.7	136.4	132.3	122.9	107.5	87.9	68.0	49.7	33.9	21.5	12.6

The energy savings, in millions of therms, is shown in Figure IV.1-4 for the two scenarios for the years 1995 through 2010. The market transformation orientation of the 1996 Constant Funding Scenario begins in 1998 and is responsible for most of the divergence in savings between the two scenarios until 2002 when funding rapidly drops to zero for the Decline After 2002 Scenario.

Figure IV.1-4


NATURAL GAS SAVINGS--2 SCENARIOS
Residential and Commercial Customers
Millions of Therms
250
200
150
100
50
0
1995
2000
2005
2010
1996 Constant Fund.
Decline After 2002

Differences in CO_2 emissions in 2010 due to the two scenarios is quite small, much smaller than the CO_2 emission reductions when the electricity demand was being analyzed (compare with Table IV.1-1).

Figure IV.1-5 shows the emissions of CO_2 due to gas demand by residential and commercial customers from 1995 to 2010. It compares emissions for the two scenarios with the emissions due to natural gas use if no new programs were offered during the period.[19] Conversions of savings in therms to CO_2 assumed 0.51 pounds of carbon per therm saved and 3.7 pounds of CO_2 per pound of carbon.[20]

Figure IV.1-5

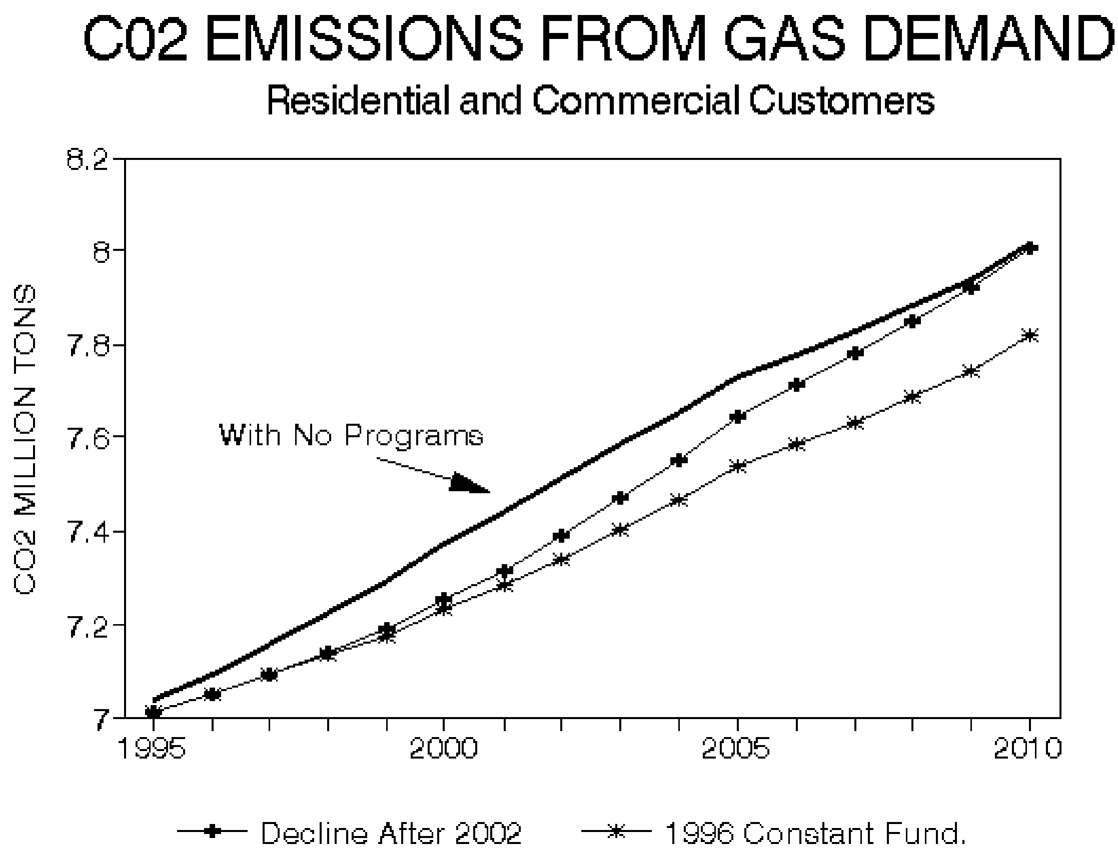


Table IV.1-5 summarizes the CO_2 emissions in millions of tons due to natural gas demand by residential and commercial customers for the years 2000, 2005 and 2010. The table includes an estimate of emissions if no energy efficiency programs were to be offered during the period. The scenarios are listed in ascending order according to CO_2 emissions in 2010.

Any long- or short-term projections of CO_2 emissions due to electrical and natural gas demand are tentative, due to the changing nature of the electric industry. Given the rapidly changing regulatory environment, two scenarios were presented--the 1996 Constant Funding Scenario and Decline After 2002 Scenario.

Table IV.1-5

SCENARIO	2000	2005	2010
1996 Constant Funding	7.2	7.5	7.8
Decline After 2002	7.3	7.6	8.0
(No Programs)	7.4	7.7	8.0

This section has estimated how the 1996 Constant Funding Scenario and the Decline After 2002 Scenario would affect CO_2 emissions due to reductions in demand for natural gas among residential and commercial customers. Very little difference appeared between the two scenarios. In addition, the actual amount of CO_2 emissions from natural gas demand among these customers is small. The most significant reductions in CO_2 emissions apparently will be made through energy efficiency programs aimed at reducing electrical consumption rather than through similar programs aimed at reducing natural gas consumption.

CO_2 Emissions: Combined Electricity and Natural Gas Efficiency Program Effects

Table IV.1-6 combines the findings from the previous two sections of this report. It shows the CO_2 emissions from commercial and residential customers due to demand for electricity and gas, and the effects of the 1996 Constant Funding and Decline After 2002 Scenarios on those emissions. It summarizes Table IV.1-1 and Table IV.1-4 above.[21]

Table IV.1-6
CO_2 Emissions due to Electricity and Gas Demand by Residential and Commercial Customers (Millions of Tons)

SCENARIO	2000	2005	2010
1996 Constant Funding	103	110	118
1994 Constant Funding	103	112	119
Decline After 2002	103	112	121
(No Programs)	107	117	126

In the year 2000, all scenarios have the same CO_2 emissions (four million tons less than if no programs were in place). In 2005, the 1996 Constant Funding scenario saves two million tons more than the scenario where program efforts decline after 2002. In 2010, the 1996 Constant Funding Scenario saves one million tons of CO_2, compared to the 1994 Constant Funding Scenario, and saves three million tons of CO_2 more than the scenario where program efforts decline after 2002.

Conclusions

This analysis has used scenarios to deal with the uncertainty with respect to future energy savings, given the state's changing energy structure, including: 1) 1994 Constant Funding; 2) 1996 Constant Funding; and, 3) Declining Funding After 2002, covering the time period from 1994 to 2010 for each scenario. Estimates of potential reductions of CO_2 emissions and energy savings resulting from different levels of funding for publicly-financed electricity and natural gas efficiency programs, from the years 1995 to 2010, have also been presented.

Certain energy saving technologies, and associated reductions in CO_2 emissions, will be promoted by the energy efficiency programs listed in Table IV.1-2a. Major technologies expected to reduce electricity demand in the residential and commercial customer classes over the next decade include improved refrigeration and lighting, heating, ventilation and air conditioning (HVAC) measures. Estimated natural gas savings and their associated CO_2 emissions reductions have been analyzed by developing two scenarios for the programs. The findings on CO_2 emissions from commercial and residential customers due to demand for both electricity and gas have been combined, showing the effects of the 1996 Constant Funding and Decline After 2002 Scenarios on those emissions. In reviewing these findings, it becomes apparent that the most significant reductions in CO_2 emissions will be made through energy efficiency programs aimed at reducing electrical consumption, rather than through similar programs to reduce natural gas consumption.

Because of the rapidly-changing nature of the electric industry, any long- or short-term projections of CO_2 emissions due to electrical and natural gas demand are tentative. Anticipated energy savings from new "market transformation" type programs are speculative, and there are currently few estimates of energy savings or load impacts of existing market transformation program designs. A concerted future effort will be needed to develop methods to measure market transformation impacts on energy efficiency programs in all sectors. The scenarios analyzed provide a range of plausible estimates of likely energy savings and CO_2 emissions reductions from energy efficiency programs for the utilities' residential and commercial customers.

IV.2. Industrial Emissions Reduction Strategies

California's industries are among the most diverse in the nation. The *1991 GCC Report* discussed industries considered to be major contributors to carbon dioxide emissions and made recommendations on how California, and the Energy Commission in particular, can influence the industrial sector to reduce such emissions. This section provides additional perspective on California's industries and describes current programs designed to reduce industrial CO_2 emissions.

California's industrial sector, composed of approximately 50,000 businesses, consumes 25 percent of all electricity, and 30 percent of all natural gas, in the state. Industry is centered mainly in large urban areas such as Los Angeles, the San Francisco Bay area and other major cities. Approximately 1,200 (3 percent) of industries are considered large energy users and, therefore, are substantial contributors to CO_2 emissions. Many of these facilities, while not always large or major employers, are subject to oversight regarding air emissions and are known to either the Energy Commission or one of the other state oversight agencies. The remaining 97 percent is comprised of much smaller energy users.

The 1991 report highlighted the potential to reduce CO_2 emissions by adopting cost-effective, high efficiency technologies. Experience since then has been that industry adoption of these technologies is slow. However, new efforts underway to improve the accessibility of information regarding energy-efficient technologies promise to increase the adoption rate. Issues of deregulation and restructuring of the utility industry could have either negative or positive impacts, depending on their final outcomes, the structure of new markets, and funding available to support industrial energy-efficiency improvements.

Because industrial sector programs to reduce CO_2 have been voluntary and have no set targets for reducing emissions, and also because of the uncertainty surrounding changes in publicly-financed funding for energy efficiency programs, there is no way to predict at this time the extent of GHG emissions reductions that could be achieved with specific strategies.

Voluntary Industrial Emissions Reductions Strategies

Since the early 1990s, the federal government has sponsored a number of programs designed to reduce industrial CO_2 emissions. The Energy Commission is participating in these programs, in collaboration with industry and other state agencies, and has undertaken a number of initiatives. Like many other sectors, the industrial sector is not necessarily knowledgeable regarding the costs of energy consumption. Although many industries, particularly those with energy-intensive operations, recognize energy costs as substantial, some are unaware of the potential for energy-efficiency improvements or have concerns about the risk of investing in energy efficiency improvements. California's approach to these concerns is based on the concept that combining energy efficiency with environmental compliance, mitigation and improved productivity is more likely to entice industry to adopt emission-reduction measures than concentrating solely on reducing CO_2 emissions. In cooperation with other state and federal agencies and organizations, the Energy Commission is focusing its efforts on the following programs:

National Industrial Competitiveness through Energy, Environment and Economics ($NICE^3$) Program

The $NICE^3$ program, initially sponsored by both the Department of Energy (DOE) and the Environmental Protection Agency (EPA), encourages manufacturing industries to adopt innovative processes that will result in improved energy efficiency, environmental performance, enhanced business performance and profitability. Operated on a competitive basis, this cost-sharing program requires states to partner with industrial firms to submit proposals, which are then competitively-ranked and funded. Projects selected must demonstrate commercial readiness and a high degree of transferability to other industries in the state.

California competes in this program annually, and has formed a coalition of state agencies that works collaboratively to ensure that high-quality proposals are developed and submitted. Seven demonstration projects are currently underway in the state, with initial results indicating good likelihood of success. The Energy Commission intends to work actively to disseminate the benefits of these projects to related industries throughout California. These projects, and the transferability of these technologies to other industries, will broaden efforts to reduce statewide CO_2 and other emissions. Currently-funded technologies and their applications include:

Industry	**Technology**
Pulp and paper	Closed-cycle, chlorine-free bleaching
Brick and clay products	High-efficiency, low-thermal mass kiln
Plastics	Recovery and separation of high grade scrap
Electronics	Vapor cleaning to replace acid stripping
Metals finishing	Durable coatings using vapor deposition
Food Industry	Membrane technologies for closed-cycle water use
Food industry	High-efficiency/low-operating-temperature Evaporative heat pump

Motor Challenge Program

The *1991 GCC Report* outlined the potential benefits of industry adoption of energy-efficient motors and drives. DOE's voluntary Motor Challenge Program (MAP) is aimed toward optimizing the efficiency of motor-driven systems within manufacturing industries. A report commissioned by the program identified electric motors as responsible for approximately 70 percent of all industrial energy use. Traditional utility programs have generally only encouraged industry to install variable speed drives, or to change out or specify energy-efficient motors for their systems, largely ignoring the larger potential benefits of better system design and optimization. Using traditional utility incentive or rebate programs has led, in some instances, to inappropriate changes or additions that failed to provide energy savings and, consequently, emissions improvements.

The Motor Challenge initiative seeks to recruit motor users, suppliers, designers and repairers to form partnerships to optimize the design and operation of industrial motors and to demonstrate to, and educate, users on preferred designs and operation of a motor-driven systems. California has further developed the state's approach to the program to include an Industry Advisory Panel that actively provides training, workshops, educational materials and an element of technical support to manufacturing industries. Due to the high energy use by motors in industry, and the potential for improving the efficiency of motor systems (with consequent reductions in energy use and CO_2 emissions), this program has immense promise, and California_s activities are likely to bring large rewards.

Industrial Assessment Centers (IACS)

Through this program, DOE provides industry with technical resources to assist in identifying opportunities for energy efficiency improvements. This free service is currently offered by DOE through San Francisco State University and San Diego State University, which have formed special teams of engineering students to carry out audits and provide recommendations on energy efficiency and waste-minimization. Current funding for the two IACs currently allows for only 60 audits per year; however, according to the IAC's,
50 percent of recommended improvements are undertaken. The Energy Commission is currently working with the IACs to more widely promote these services, which includes presenting workshops to provide information and a self-help package designed to allow industry participants to conduct simplified energy and waste-minimization audits on their own, followed by more detailed audits by the IACs.

Climate Wise Program

Another voluntary program, sponsored by both the DOE and EPA, is designed to encourage industries to examine and adopt energy efficient GHG emissions reduction strategies that will also improve the organization's profitability. The Energy Commission joined the Climate Wise initiative in 1996 and is expecting to recruit over 100 new members from across all industrial areas. In a manner similar to its partnership with the NICE[3], the Energy Commission is cooperating with sister agencies, the California EPA and other Resources Agency departments, to demonstrate that voluntary activities may be preferable to new regulations and additional oversight. Technical assistance from the IACs is available, along with Climate Wise software designed to help participants analyze the financial effects of proposed actions and develop viable action plans. Industries' primary motivation for participating in this initiative is positive recognition by both other industries and the general public. Many companies now use involvement in the Climate Wise program to demonstrate the environmentally-conscientious manner in which their products are being manufactured.

Alternative California Oil/Natural Gas Production Technologies

The oil and gas recovery industry contributes significantly to CO_2 emissions in California, representing about 20 percent of emissions from all industries. Petroleum products are obtained by refining crude oil, which varies in quality. Enhanced Oil Recovery (EOR) is the process required to extract oil from a petroleum reservoir after primary and secondary recovery methods have been employed. Conventional recovery of oil discovered in the United States has left behind about 300 billion barrels of oil in known reservoirs. The target of EOR extraction is the estimated two-thirds of the oil left in the reservoir after conventional production, which is not recoverable using conventional methods due to high viscosity, low energy, and unfavorable reservoir geology. It is estimated that about 30 billion barrels could be recovered using current EOR techniques, while the remaining oil is the target of new EOR technologies under development. Because the United States is a mature oil producing area, future recovery from known reserves will have to be through these unconventional means.

Strategies to enhance oil and gas recovery have been highly focused on economics; however, some new technologies have the potential to reduce CO_2 and other GHG emissions.

The three EOR methods that have shown significant commercial potential for recovering additional oil from known reservoirs are thermal enhanced oil recovery, chemical flooding, and gas displacement methods. The various processes that fall within these classifications differ considerably in their physical mechanisms to recover oil, their level of technical maturity, and their potential for commercial development. These new technological approaches will have varying impacts on greenhouse gas emissions. The price of oil which, until recently, had seen particularly low levels, has a dramatic impact on the economics of oil extraction using the new technologies, and their adoption cannot, so far, be proven to be cost effective.

Thermal Enhanced Oil Recovery (TEOR)

Thermal Enhanced Oil Recovery (TEOR) processes, which add heat to the reservoir to reduce oil viscosity, are currently the primary EOR method, used for producing almost 60 percent of EOR oil in the United States. Lowering a fluid_s viscosity increases its mobility, allowing it to move through the formation to producing wells. In addition, TEOR processes add pressure to the formation, which exerts a driving force on the oil. The two principal types of TEOR are steam injection and in-situ combustion, processes which are particularly effective for heavy oil.

Steam injection has been commercially applied since the early 1960s, but is not considered efficient. Steam generators that burn either lease crude oil, fuel oil or natural gas use approximately one out of every three barrels of recovered oil, or the equivalent energy in BTUs of natural gas. Furthermore, steam generators that burn oil must have emission control devices installed in order to comply with air quality standards. The expense of complying with air quality standards has made natural gas the fuel of choice for steam generation for TEOR projects. Many TEOR project operators are using cogeneration units to also produce electricity with the steam, the sale of which can help defray the costs of production.

In-situ combustion is another TEOR process which is applied to reservoirs containing low gravity oil. Heat is generated within the reservoir by injecting air through wells and igniting the oil in-place. The heat generated by the combustion process reduces viscosity, generates carbon dioxide, and partially vaporizes the oil. A combination of steam, hot water, and gas drive the oil forward towards the production well.

TEOR is a mature technology, with 119 projects producing more than 400,000 barrels of oil per day in the United States, although this is a 13 percent decline from a peak of more than 200 projects in operation in 1986. TEOR expansion has been limited in California because of the costs of emissions control equipment to comply with air pollution regulations. New steam generating facilities must obtain emissions offsets and are subject to Lowest Achievable Emissions Rate (LAER) criteria in non-attainment areas such as Kern County, and Best Available Control Technology (BACT) in air quality attainment areas. Due to emissions requirements, new TEOR projects may be limited to the use of natural gas, which increases the amount of greenhouse gases relative to the production of crude oil

Chemical Enhanced Oil Recovery (CEOR)

Chemical Enhanced Oil Recovery (CEOR) methods are an advancement on conventional secondary water flooding operations. CEOR techniques produce less amounts of greenhouse gases than TEOR approaches. The process consists of adding chemicals to water before injection into a reservoir to generate fluid properties that are more favorable for oil production. Chemical EOR methods include polymer flooding, surfactant flooding, and alkaline flooding processes, the most widely-applicable of which is surfactant flooding. Polymer flooding is commercially available, but too expensive for most applications. Alkaline flooding has been used only in reservoirs containing specific types of high-acid crude oils. Although surfactant flooding is expensive, it has been used in a few large-scale projects and has been demonstrated to have excellent potential for improving the recovery of low-to moderate-viscosity oils. CEOR is commercially available under limited conditions, determined by reservoir characteristics, including depth, salinity, and pH. The high cost of chemicals and reservoir characterization studies need to be reduced, to allow expanded use of chemical EOR methods at current low crude oil prices, before full commercialization can take place.

Although several examples of active chemical EOR projects exist, especially polymer flooding, the technology continues to undergo further development and testing. The number of active CEOR projects has declined significantly since 1986, and improved oil prices are key to further chemical EOR applications. The extent to which these efforts are successful will determine their success in reducing greenhouse gas emissions. In California, no oil production using CEOR has occurred since 1994.[22]

Gas Displacement

Gas displacement involves injecting gases, most commonly methane, propane, nitrogen, and carbon dioxide, into a reservoir to sweep immobile oil toward a production well. Among the miscible displacement gases, carbon dioxide, which has a moderate cost and favorable miscibility characteristics compared to the other gases, is used most often, although there are notable exceptions where hydrocarbons or nitrogen are more favored as miscible solvents. In certain cases, carbon dioxide can also be used as an immiscible drive agent. Although not as prevalent as TEOR, gas displacement still represents 41 percent of domestic EOR production. The majority of this production comes from miscible hydrocarbon or carbon dioxide displacement. Availability of carbon dioxide fluids increases as new pipelines provide access to large supplies of carbon dioxide.

The development of miscible EOR technologies depends heavily upon the value of the oil being recovered (the price of oil) and varying costs associated with extraction. The injection gas can easily cost more than half the total cost of the project and, in many cases, the value of hydrocarbon gases to industry exceeds the amount that would make most recovery projects economical. Moreover, the cost of gas varies widely throughout the nation. Carbon dioxide and nitrogen are often too costly to transport long distances, unless large quantities of recoverable oil are available. Depending on the extent of these variables, gas displacement technology can be a cost-competitive option under limited conditions. According to the Division of Oil, Gas and Geothermal Resources, only 2.4 percent of EOR oil production used gas displacement in 1995.[23]

Sources of air emissions from gas displacement EOR projects include exhaust gases from internal combustion engines or turbines used to drive the compressors and include NOx, carbon monoxide, carbon dioxide, and hydrocarbons. Sulfur oxides may also be emitted. If air emissions from the project threaten the maintenance or attainment of ambient air quality standards in the area, control devices and/or emissions offsets may be required.

Comparative CO_2 Emissions of EOR Technologies

Steam generators used in Thermal Enhanced Oil Recovery burn approximately one out of every three barrels of the oil recovered, or the equivalent energy output from other fuels. If it is assumed that, because of California's air quality requirements, TEOR would rely primarily on natural gas as a fuel, each barrel of crude oil extracted will result in net emissions of about 0.114 tons of CO_2. Using Chemical Enhanced Oil Recovery technologies reduces net carbon dioxide emissions, since the amount of fuel needed to pump treated water in the oil fields should be relatively small. The CO_2 used in Gas Displacement EOR generally comes from natural underground sources, natural gas processing or fertilizer plants. Gas Displacement EOR technologies, using carbon dioxide injection, do not actually reduce CO_2 emissions since, once the gas is injected into the oil fields, it remains trapped in underground reservoirs (they become a net sink for the gas).

Nevertheless, as indicated by the Department of Energy in its Climate Challenge Options Workbook (May, 1997), the injection of carbon dioxide from the combustion of fossil fuels is currently considered an acceptable option for reducing GHGs. The technology can be costly, since flue gases from conventional power plants require purification to meet requirements for EOR. However, existing ammonia manufacturing and coal gasification plants produce pure enough CO_2 vent gases to use directly. To improve the cost-effectiveness of gas displacement technology applications in EOR, utilities or independent producers could enter into partnerships with the oil and gas industry to utilize flue gas CO_2 from the processes mentioned above for enhanced oil recovery.

In summary, Thermal Enhanced Oil Recovery technology results in a substantial increase of carbon dioxide emissions, while using Chemical Enhanced Oil Recovery technologies reduces net carbon dioxide emissions. In the Gas Displacement EOR process, if CO_2 for injection is produced from the processes described above, it can provide a cost-effective approach to EOR, resulting in permanent carbon dioxide sequestration and no net contributions of CO_2 from oil and gas recovery.

IV.3. Electric Generation Emissions Reductions Strategies

In the *1991 GCC Report*, the Energy Commission endorsed two measures to reduce carbon emissions from electricity generation, which are discussed below: 1) accounting for environmental externalities and incorporating values in resource planning and procurement; and, 2) promoting high efficiency gas generation. A third important measure, developing and integrating renewable energy resources into the electricity generation system, is discussed in section IV.5. The Energy Commission has pursued each of these strategies, with varying degrees of success, through its 1990, 1992 and 1994 Electricity Reports, and in its 1993 and 1995 Energy Development Reports. The following sections describe the results of pursuing these strategies and the potential implications for these strategies of electricity industry restructuring.

Accounting for Environmental Externalities

In the 1991 report, the Energy Commission endorsed the concept of accounting for environmental damage from electricity generation by quantifying the environmental "externalities"[24] that powerplants may cause. The report recommended that:

- Efforts to quantify the values of externalities associated with electricity generation should be expanded and refined.

- Electric generation resource planning and procurement should be based to the extent possible on social resource costs by fully accounting for externalities.

- In the absence of a comprehensive accounting for externalities in electric generation resource planning and procurement, the Energy Commission should consider interim measures for assigning externality values to electrical generation.

The State of California has implemented these recommendations. Statutes[25]/[26] were enacted directing that the value of costs and benefits to the environment be included in the cost-effectiveness calculations for electric generation planning and procurement conducted by the CPUC and the Energy Commission.

The external costs to the environment associated with electricity production include impacts on air quality, water quality and quantity, soils, land use, and visual aesthetics. Previous research has indicated that impacts on air quality are the dominant environmental concern of the current electricity industry.[27] Thus, the focus at the planning level at both Commissions has generally been on the air quality impacts of electricity generation.

The Energy Commission has incorporated the valuing of air quality externalities to some degree in its biennial Electricity Report (ER) planning process since 1990. The California Public Utilities Commission has also incorporated the valuing of air quality externalities in its electric generation procurement process since that time.

In ER 90, the Energy Commission established residual emissions values using a "cost-of-control" methodology which assumes that the value to society of environmental damage is equivalent to the cost of preventing damage through control or mitigation measures. Beginning in ER 92, the Energy Commission used the "damage function" method which directly measures the value of environmental damage and equates the value of residual emissions --- emissions whose costs have not been accounted for through regulations or market-based allocation systems --- to the damage they cause.

In ER 94, the Energy Commission estimated damage costs for the five "criteria" pollutants[28] for which ambient air quality standards have been established, as well as carbon dioxide (CO_2), for seven individual air basins in California and the two regions outside of California from which we import all of the electricity not generated inside the state. Projected externality costs associated with residual emission damages are listed in ER 94, Appendix A, Part II, a copy of which is provided with this report.

These residual emissions costs[29] were used to analyze the cost-effectiveness of adding resources to reduce the total social cost of electric generation in the four largest utilities[30] in the state as follows. First, detailed economic analyses using an electricity production cost model and automated capacity expansion model were conducted to assess whether those utilities could add new powerplants in order to lower costs to their customers. (Because they are typically more efficient, new powerplants have total costs --- both capital and operating --- that can be less than the operating costs of existing plants that the new plants would replace.) This resulted in a "private cost" case or "reference case" that showed the costs[31] and benefits to customers of potential powerplant additions. Then, emission values were added to the economic parameters and the analyses were redone. This resulted in a "social cost" or "external cost" case which reflected the total costs[32] and benefits to society of adding new plants.

Including those external costs usually results in making new additions more economic and, thus, cost-effective one to three years earlier. This is because all new plants are generally cleaner and more efficient than existing plants. Typically, the new resources use less fuel and emit fewer pollutants per kilowatt of output than existing units. By reducing total system emissions and fuel use, the new powerplants can reduce total system social costs. The Energy Commission has consistently found in its last three ERs that including residual emission values makes new resources become cost-effective a few years earlier than they would have been otherwise.

The Energy Commission has also consistently found that gas-fired powerplants, (either repowers of existing facilities, new combined cycles or combustion turbines to fill in peaking gaps), rather than changing the types of resources that are the most cost-effective from the private-cost case, were generally the least-cost resource choice, even when a social cost decision criterion is used. This is because new natural gas plants are low in cost and sufficiently clean so that adding externality values does not increase system social costs above the same costs when alternatives are modelled.

In ER 94's private cost case, which included the cost of air emissions offsets and marketable permits, combined cycles were the predominate cost-effective resource addition. Valuing damages from residual emissions in ER 94's social cost case hardly affected the choice of powerplant additions--combined cycles generally remained the most cost-effective resource additions. New geothermal and wind powerplants did become the most cost-effective resources in some cases, but not until very late (around 2010) in the 20-year planning period.[33] Further, the cumulative total costs[34] for the state's electricity system between 1994 and 2013 differed only by about 18 thousandths of one percent--only $21 million out of total costs of $114 billion (net present value in 1994 dollars)--between the private cost and social cost cases. (See Table IV.3-1)
Valuing the damages caused by residual emissions has so little effect on the type of resource addition found to be most cost-effective because:

- the quantity of system residual emissions decreases over time as emission control retrofits are placed on existing units and as new, more efficient and cleaner resources are added;

- the costs of many residual emissions are already internalized by market-based regulations such as offsets and marketable permits; and

- investing in new powerplants is an expensive way (along with DSM and EVs) of reducing residual emissions. The cost of building and operating new powerplants is an order of magnitude greater than installing pollution control equipment on existing powerplants, so many emissions reductions benefits are needed to pay the costs.

That valuing residual emissions has so little effect on the type of resource addition found to be most cost-effective is, ironically, a result of the severity of California's air quality problem. California has so many areas where ambient air quality standards are violated that a fossil-fueled powerplant sited in California generally must provide offsets[35] for many of the emissions which are assigned damage costs and must use the best available control technology for its source category.

Thus, for ER 94's social cost purposes[36], the fossil-fired powerplant was modelled as having no net residual emissions costs for those emissions for which it must provide offsets.

There are relatively few residual emissions that can be cost-effectively reduced or avoided by new non-emitting powerplants. After 1999, California's gas-fired powerplants will participate in the federal Clean Air Act's SO2 Allowance program which is modelled as internalizing the cost of their SO2 emissions. In northern California, Pacific Gas and Electric (PG&E) and the local air districts have agreed to retrofit a substantial number of older, large gas-fired powerplants with NOx emission controls and PG&E has already retired, or plans to retire, a substantial portion of the rest. In southern California, the South Coast Air Quality Management District's Regional Clean Air Incentives Market (RECLAIM) program is modelled as internalizing much of the cost of continuing to produce NOx emissions. The Ventura County Air Pollution Control District's Rule 59 has required Southern California Edison to retrofit all of its gas-fired boilers in that county with the equivalent of best available retrofit control technology. The San Diego County Air Pollution Control District has come to agreement with San Diego Gas and Electric (SDG&E) to put all of its boilers under a system NOx emission cap that will effectively require SDG&E boilers to achieve best available retrofit technology emission limits by the turn of the century. Taken together, these measures reduce the amount of allowed emissions (the residual emissions) from existing powerplants, or switch the cost of those emissions from the "external" or social cost calculation to the private cost calculation.

The results of valuing residual emissions on the amount of CO2 emitted by electric generation system are mixed. If both in-state and out-of-state CO2 emissions are totaled, the social cost case is 900,000 tons lower than the private cost case in 2013. (See Table IV.3-2) If only in-state CO_2 emissions are counted, the case without residual emissions valuing is actually 300,000 tons lower in 2013 than the case that incorporates residual emissions valuing. (See Table IV.3-3)

Table IV.3-1. Capacity Expansion Plan Cost Data by Utility Planning Area Cumulative Present Values 1994-2013 (1994 Beginning of Year Million$)

	Production	Shortage	Fixed O&M	Capital	Private Costs	**Emissions**	**Total Cost**
Southern California							
Base Case	$37,453	$896	$107	$0	$38,456	$11,536	$49,992
Private Costs	$36,162	$459	$255	$1,017	$37,892	$11,344	$49,236
Social Costs	$36,262	$469	$238	$892	$37,860	$11,365	$49,225
Private - Social	($100)	($10)	$18	$125	$32	($21)	$11
Pacific Gas & Electric							
Base Case	$40,867	$635	$0	$0	$41,501	$2,187	$43,688
Private Costs	$39,434	$177	$175	$776	$40,563	$2,112	$42,675
Social Costs	$39,408	$160	$180	$817	$40,565	$2,107	$42,672
Private - Social	$26	$17	($4)	($41)	($2)	$5	$2
San Diego Gas & Electric							
Base Case	$7,348	$492	$104	$0	$8,372	$1,103	$9,476
Private Costs	$6,292	$94	$191	$515	$7,092	$1,046	$8,137
Social Costs	$6,337	$34	$213	$680	$7,264	$912	$8,176
Private - Social	($44)	$60	($23)	($166)	($172)	$133	($39)

Los Angeles Dept. of Water & Power							
Base Case	$10,110	$0	$0	$0	$10,110	$3,537	$13,647
Private Costs	$10,020	$0	$0	$85	$10,105	$3,520	$13,625
Social Costs	$9,929	$0	$11	$180	$10,121	$3,500	$13,621
Private - Social	$91	$0	($11)	($96)	($16)	$20	$4
Statewide w/o SMUD							
Base Case	$95,776	$2,023	$211	$0	$98,439	$18,364	$116,803
Private Costs	$91,908	$730	$621	$2,392	$95,652	$18,021	$113,673
Social Costs	$91,936	$663	$642	$2,569	$95,810	$17,884	$113,694
Private - Social	($28)	$67	($20)	($178)	($158)	$137	($21)

While this result is consistent with the Environmental Protection Agency's CO_2 reporting requirements, it seems counter-intuitive. The reason for this result is that the total cost of the other five criteria pollutants drives the capacity expansion process to:

- reduce the use of existing gas-fired powerplants by adding new cheap, efficient, cleaner combined cycles that must purchase offsets;
- replace existing gas-fired powerplants with cheap, efficient repowerings with state-of-the-art emission control technologies; and,
- retrofit existing gas-fired powerplants with emission control devices.

All of these actions have significant effects on the emission of the five criteria pollutants, but not on CO_2, except when increases in efficiency reduce the amount of fuel, and therefore carbon, that must be combusted to generate a kilowatt-hour. Since California has severe air quality problems related to criteria pollutants, it is not likely that a planning approach that includes values for all residual emissions would place enough weight on CO_2, alone, to consistently produce electric generation resource plans that reduce CO_2 emissions over plans that did not value residual emissions.

The utility grid is interconnected across state lines and power is imported to, and exported from, California. Therefore, a complete analysis of the effects of electricity generation emission reduction strategies must account for effects on both in-state and out-of-state CO_2 emissions, as shown in Table IV.3-2. EPA, at the federal level, should then reconcile the emissions results among states.

In conclusion, these and other findings led the Energy Commission to adopt the recommendation, in its *1994 Electricity Report* (November, 1995), that broad-based market-oriented internalization policies should be established to balance social costs with social benefits. Although continuing the Energy Commission's support for internalizing the externalities of energy use, this recommendation moved away from previous policies of doing so through centrally-planned, administratively-established, above-market subsidies or set-asides, the cost of which would largely be borne by electricity ratepayers alone. The Energy Commission recommended that the state should:

- regardless of the degree of regulation or competition, reaffirm its commitment to internalizing externalities by establishing "alternative methods" such as "marketable permit programs or surcharges on residual emissions;"
- equitably establish cost-effective methods of internalizing externalities in all sectors, not just electricity production;

- coordinate an efficient, broad-based, market-oriented internalization policy that crosses regulatory agency boundaries;
- enhance the quantitative basis for internalization by documenting the extent and effects of both in-state and out-of-state externalities; and
- during the transition period, continue to use existing tools, such as environmental performance standards, “to induce actions consistent with broader market-based methods.”

Table IV.3-2

Private Cost Case
Millions of Tons of CO_2

	1995	2000	2005	2010	2013
SCE	46.6	48.2	50.0	54.3	56.3
PG&E	28.8	32.3	34.4	37.4	39.6
SDG&E	9.1	8.6	8.9	10.0	10.4
LADWP	18.4	19.6	20.7	21.5	21.3
SMUD	0.0	0.8	1.5	2.0	2.5
TOTAL	102.9	109.6	115.5	125.3	130.1

Social Cost Case
Millions of Tons of CO_2

	1995	2000	2005	2010	2013
SCE	46.6	48.2	50.0	54.3	56.3
PG&E	28.8	32.3	34.5	37.4	39.5
SDG&E	9.1	7.8	8.8	9.7	10.5
LADWP	18.4	19.6	20.4	20.4	20.4
SMUD	0.0	0.8	1.5	2.0	2.5
TOTAL	102.9	108.8	115.2	123.9	129.2

Private Minus Social Cost Case
Millions of Tons of CO_2

	1995	2000	2005	2010	2013
SCE	0.0	0.0	0.0	0.0	0.0
PG&E	0.0	0.0	-0.1	0.0	0.1
SDG&E	0.0	0.8	0.2	0.2	-0.1
LADWP	0.0	0.0	0.3	1.1	0.9
SMUD	0.0	0.0	0.0	0.0	0.0
TOTAL	0.0	0.8	0.3	1.4	0.9

Table IV.3-3
In-state Only Private Cost Case
Millions of Tons of CO_2

	1995	2000	2005	2010	2013
SCE	26.4	28.6	30.0	34.5	37.4
PG&E	25.0	27.8	29.9	33.0	35.1
SDG&E	4.3	6.1	7.2	8.2	9.0
LADWP	4.0	4.2	5.1	4.9	4.5
SMUD	0.0	0.4	0.9	1.4	1.8
TOTAL	59.7	67.1	73.2	82.0	87.7

In-state Only Social Cost Case
Millions of Tons of CO_2

	1995	2000	2005	2010	2013
SCE	26.4	28.6	29.9	34.5	37.4
PG&E	25.0	27.8	30.0	33.0	35.0
SDG&E	4.3	6.1	7.2	8.2	9.0
LADWP	4.0	4.2	4.9	5.1	4.8
SMUD	0.0	0.4	0.9	1.4	1.8
TOTAL	59.7	67.1	72.9	82.2	88.1

Private Minus Social Cost Case
Millions of Tons of CO_2

	1995	2000	2005	2010	2013
SCE	0.0	0.0	0.1	0.0	0.0
PG&E	0.0	0.0	-0.1	0.0	0.1
SDG&E	0.0	0.0	0.1	0.1	0.0
LADWP	0.0	0.0	0.2	-0.2	-0.4
SMUD	0.0	0.0	0.0	0.0	0.0
TOTAL	0.0	0.0	0.2	-0.1	-0.3

Conclusions

Since *ER 94*, the California Public Utilities Commission adopted its December 20, 1995 order on restructuring California's electricity industry and the state legislature passed AB 1890 in the fall of 1996, which further refined California's electricity industry proposal. Enactment of these measures has, for all practical purposes, eliminated the processes used in ER 94 for valuing air quality externalities. Nevertheless, the statutes still exist which require the Energy Commission and California Public Utilities Commission (see Endnotes 25 and 26) to include a value for the costs to the environment in determining the cost effectiveness of energy resources. The Energy Commission remains committed to pursuing the state's long-run goal to increase application of broadly-based, market-oriented environmental policies as a way to improve the balancing of social costs and benefits.

In ER 96, the Energy Commission's efforts to examine alternative means of balancing social costs and benefits has focused on criteria pollutants, and not on methods to internalize the damages associated with CO_2 emissions from electricity generation. However, some conclusions reached in the *ER '96 Committee's Draft Final Report* (June, 1997) regarding internalization policies for criteria pollutants are also relevant to internalizing CO_2 damages:

- The goal of balancing economic, energy, and environmental concerns remains as valid as it was when the legislature adopted PRC 25000.1, but can be better served with an approach to environmental policy that is consistent with a competitive market and with other state and federal regulations affecting the electricity generation industry.

- The most economically efficient method to balance social costs and benefits in a competitive electricity market is through the use of economic incentives, which help ensure that siting and operations decisions account for environmental costs, thus promoting economical, environmental, and efficient growth throughout the state.

- Well-designed incentive programs should include as many emissions sources as possible, given the costs and benefits of including those sources. This is not only equitable, but the more sources included, the greater the opportunities for cost-savings, faster air quality benefits, and stronger incentives for technological innovation. Including only major sources, such as powerplants, may exclude potentially lower-cost emission reduction opportunities from smaller sources which, in aggregate, contribute a much larger share of emissions.

- Each source should bear environmental costs in proportion to the harm from their emissions. When firms bear the total costs of their actions, then siting, operation, and shutdown decisions lead to the most efficient number and types of firms, with appropriate investments in new emission reduction strategies.

IV.4. High-Efficiency Gas Generation Technologies

Over the past thirty years, the most prevalent natural gas-fired bulk power in California has been delivered by steam turbine power plants which produce power at about 32 percent efficiency. These plants serve, along with oil-and distillate-fired systems, in the mix of fossil fuel-fired generation of electricity. In recent years, gas turbine systems fueled by natural gas have begun to replace some of the older natural gas-fired steam units and to satisfy new utility load growth. Gas turbines have the advantage of improved thermal efficiency (compared to natural gas-fired steam units) and high temperature exhaust, which can be captured for other energy uses. When a gas turbine is operated without capturing the hot exhaust energy it is called a simple cycle. Simple cycle gas turbine efficiency percentages range as high as the mid-to-high 30 percent.

For power generation, the hot exhaust can be used to make steam for use in a separate steam turbine, resulting in combined cycle generation. The overall efficiency of combined cycle systems can reach into the mid-50 percent range. Higher efficiency in combined cycles is closely matched with increasing capital costs and diminishing returns are soon reached.

Strategies for Reducing CO_2 Emissions

Although natural gas-based generation technologies are substantially commercialized, research, development and demonstration funding is needed to design and demonstrate advanced, high-efficiency gas (HEG) turbines. Power generation systems currently under development hold much promise for significantly improved fuel efficiency and corresponding reductions in carbon dioxide emissions. For advanced natural gas generation technologies, carbon dioxide emissions will be inversely proportional to the thermal efficiency of the generation cycle. These systems include the Advanced Turbine System (ATS) under development by multiple vendors under funding from DOE, the Chemically Recuperated Gas Turbine Cycle system, and Fuel Cell/Gas Turbine hybrid systems. The ATS machines will be a family of next-generation gas turbines ranging in size from just a few megawatts (MW) to over 200 MW. These gas turbines are under development by several U.S. manufacturers and field tests are scheduled to begin near the end of the century. These gas turbines will exceed their predecessors in several cost and performance areas. Fuel efficiency is expected to be in the mid-40 percent range in simple cycle operation, and over 60 percent in combined cycle operation.

The Chemically Recuperated Gas Turbine, or CRGT is based on an intercooled gas turbine machine. The turbine gains efficiency by using exhaust heat to create fuel for the turbine in a process called chemical recuperation. Exhaust gas, natural gas, and steam are mixed and passed through a catalytic reactor to produce a very clean burning synthetic fuel gas which is then delivered back to the turbine to be burned with pipeline natural gas. The net fuel efficiency (considering both the natural gas burned directly from the pipeline and that used to make synthetic fuel gas) will be about 54 percent. This technology is expected to be available over a longer-term period.

Fuel cell/gas turbine hybrids will take advantage of the synergy between these two types of systems. High temperature exhaust heat from the fuel cell will preheat combustion air for the gas turbine, thus reducing the amount of fuel required to generate full power. Many different combinations are possible because of the variety of fuel cells and gas turbines either available or under development. An optimized system will have fuel efficiency of about 70 percent with generating capacity in the 20 MW range.

Conclusions

Table IV.5-1 shows the potential for fuel efficiency and CO_2 emissions reductions, compared to current baseline, of advanced HEG generation technologies.

Table IV.4-1
CO_2 Reduction of High-Efficiency Gas Generation Technologies

Natural Gas Generation Technology	Fuel Efficiency (%)	Heat Rate (BTU/kWh)	CO_2 Reduction Compared To
Baseline: Steam Turbine	32%	10,666	
Conventional Gas Turbine (simple cycle)	36%	9,508	11%
Conventional Gas Turbine (combined cycle)	51%	6,692	37%
ATS Gas Turbine (simple cycle)	43%	7,937	26%
ATS Gas Turbine (combined cycle)	60%	5,688	47%
Fuel Cell/Gas Turbine Hybrid	70%	4,876	54%

IV.5. Developing and Integrating Renewable Generating Technologies

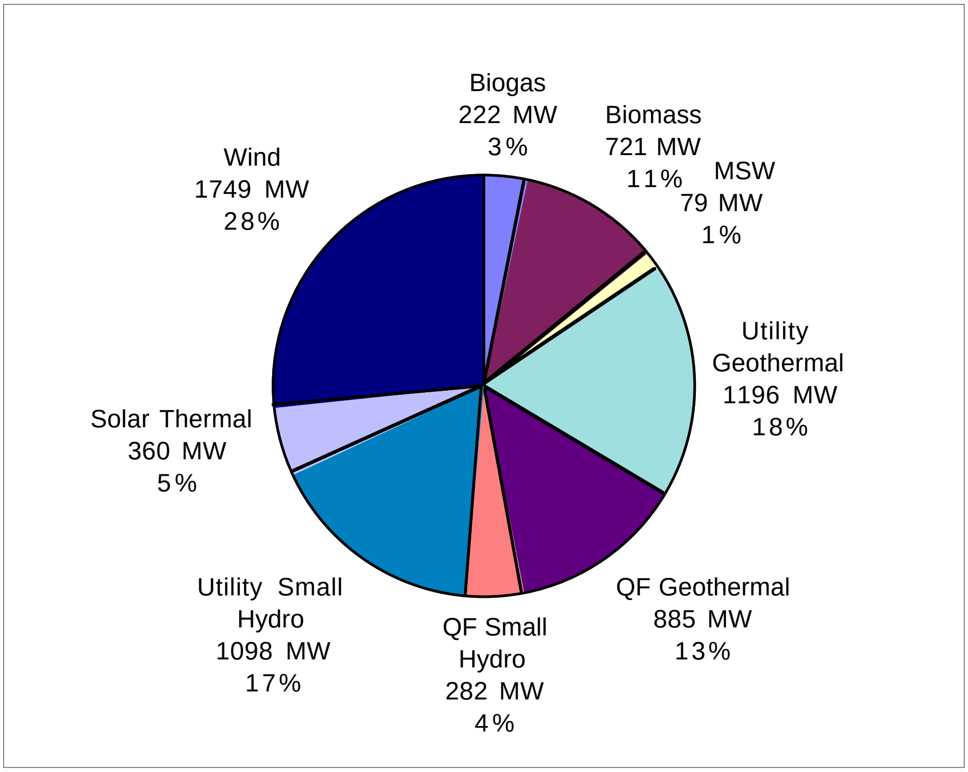
In its previous Global Climate Change Report, the Energy Commission endorsed promoting the development and integration of renewable generation technologies into the electricity system to reduce climate change emissions. The report recommended expansion of efforts to accelerate renewable technologies through research, development, demonstration, and commercialization activities. The state of California has, for nearly two decades, supported RD&D program funding specifically targeted to high-priority renewable technologies and to commercializing "opportunity" technologies -- those that can help California move towards a cleaner, less expensive, and more secure energy future. Further, as discussed in Chapter II of this report, in the current climate of electric utility industry deregulation and restructuring, California is continuing to ensure that a portion of new generation resources will be renewable resources, while assisting energy suppliers in moving toward market-oriented provision of these resources.

Historical Renewable Policies

Since the early 1980s, California has developed the largest and most diverse renewable resources generation industry in the world. California's 1996 energy mix included slightly over 29,000 GWh of independent-producer and utility-owned renewable energy, consisting of solid-fuel biomass, geothermal, wind, small hydro, solar and municipal solid waste (MSW) facilities, producing 11 percent of all electricity used. Figures IV.4-1 and IV.4-2 show the relative capacity (MW) and generation (GWh) shares, respectively, of the technologies comprising California's renewable power industry.

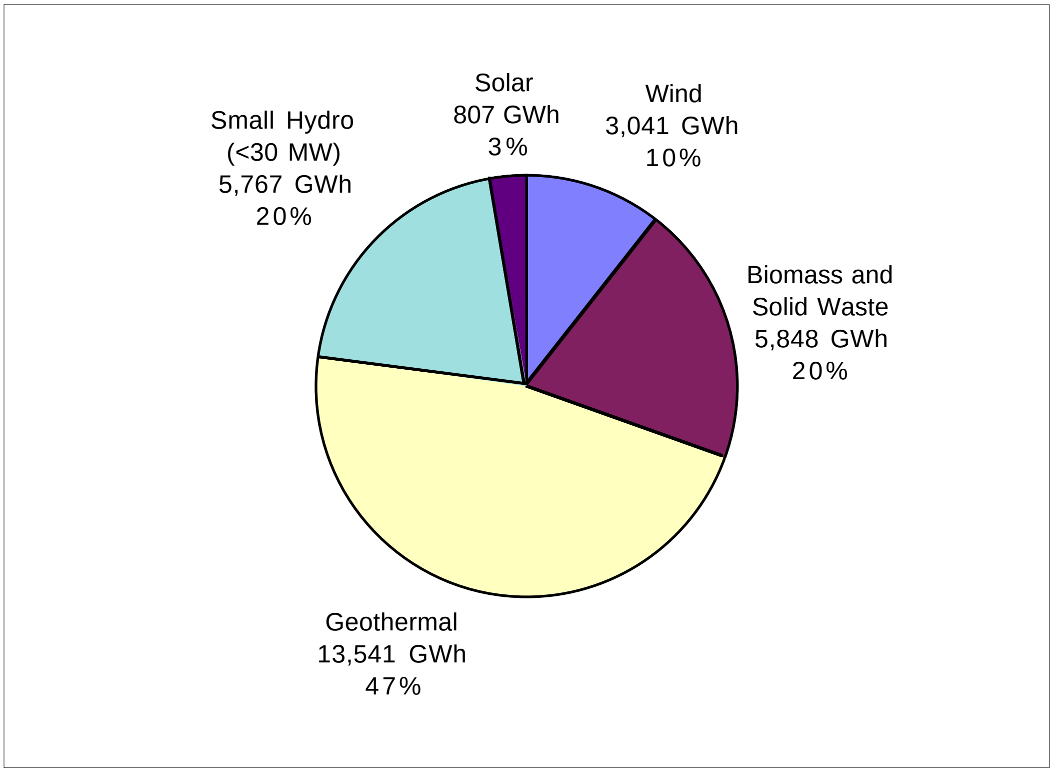
California's support for developing renewable resources has been targeted primarily to ensuring sustainable energy supplies for the state and decreasing fossil-fuel emissions to meet statewide economic, energy-efficiency, and air quality goals. In recent years, the contribution of various energy supply options to global climate change emissions has also been a consideration. In balancing these goals over many years, the Commission has rigorously analyzed all viable supply-side options for the state and recommended a variety of renewable development policies.

Figure IV.5-1: California's In-State Renewable Capacity, 1996 (Estimated)



This figure includes estimates of both utility-owned and non-utility owned renewables generation, but no self-generation. Qualifying Facility capacity is based on the Energy Commission's QF database that includes data from the utilities' quarterly status reports on small power producers.

Figure IV.5-2: California In-State Renewable Generation, 1996



Sources for data are the *Staff Report, Preliminary Net System Power For 1997,* November 20, 1997.

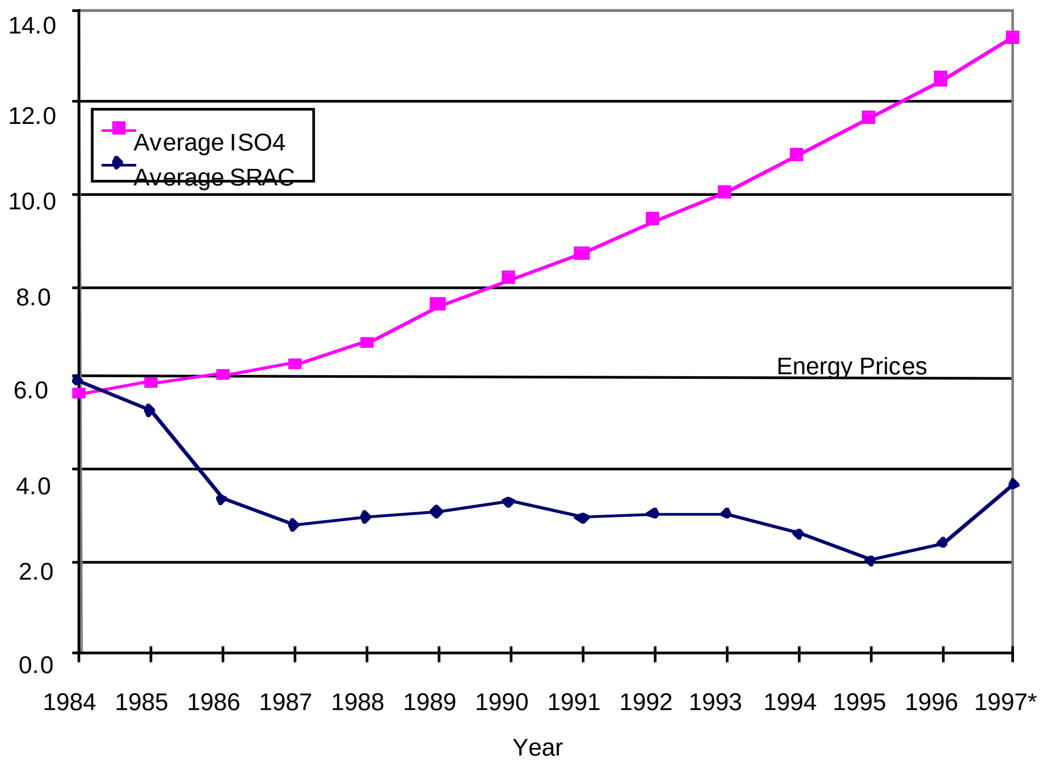
Renewable Power Industry

California's renewable power industry was spurred by the state's aggressive implementation, in the early 1980s, of the federal Public Utility Regulatory Policies Act of 1978 (PURPA), which provided guidelines for state regulations to support growth of non-utility electricity suppliers. PURPA was implemented through three types of "standard offer" (SO) contracts, plus an interim standard offer contract (ISO4), that required the state's IOUs to purchase the output of independent generators (also known as qualifying facilities), many of which were renewable. Most non-utility renewables in California were built under ISO4 contracts, which provided fixed energy (per kWh) payments for up to 10 years (based upon the IOU's forecasted avoided energy costs[37] over that period), as well as fixed-capacity payments (per kW) for the term of the contracts.[38] Guaranteed energy and capacity payments helped to attract financing for independent energy projects.

In the 11th year of the ISO4 contracts, the fixed energy prices convert to variable prices tied to the utilities' current "short run avoided costs" (SRAC). These costs are calculated monthly by the IOUs using an agreed upon formula, currently related to the California border price of natural gas. When ISO4 contracts were signed, SRACs were expected to increase over time.
Instead, they decreased significantly in the late 1980s, and, except for occasional short-term increases, have since remained at low levels.

This situation has created what is known as an energy "price cliff" for the ISO4 contracts. SRAC prices are as much as 85 percent less than the fixed prices received at the end of the 10 year period. As these facilities move into the variable-energy-price period of their contracts they face sharply lower payments for energy produced. Figure IV.3-3 shows past and present SRAC energy prices compared to fixed ISO4 energy payments (average for PG&E, SCE and SDG&E), and illustrates two points. First, projects that are still in the fixed energy price portion of their ISO4 contracts are receiving energy payments far in excess of current SRAC levels. Second, facilities with higher variable costs will have difficulty continuing to operate after they “fall off the cliff,” when they receive sharply less revenue, even with the continued fixed-capacity payments.

Figure IV.5-3: Comparison of ISO4 and SRAC Energy Prices (Average of PG&E, SCE, SDG&E SRAC Levels)



*1997 SRAC price includes January, February, and March only; the annual average for 1997 may be significantly different.

Regular increases in renewable energy supplies were seen throughout the late 1980s and early 1990s. However, since 1993, as SRAC prices have dipped below historic levels, renewable generation has decreased in California. Nearly 20 biomass plants comprising 200 MW of generation, most of which had ISO4 contracts terminated by negotiation, have gone off-line. Wind capacity has decreased by over 100 MW since 1993, primarily because some machines have been shut down and used for parts to keep others operating. Further decreases can be expected if energy prices remain low, particularly as more facilities come "off the cliff" of their ISO4 contracts. Procuring new renewable resources can potentially mitigate the decreased capacity of existing facilities that are not competitive at recent energy prices.

Biennial Resource Plan Update (BRPU) and Set-Asides

As described in Chapter II of this report, prior to industry restructuring, California’s new electricity resources were developed through a biennial Biennial Resource Plan Update (BRPU) process. The process generally included a reserved portion of the assessed need that was set aside

for renewable resources. The amount of determined need, including the renewable "set-asides," was allocated every two years to various projects and resource types.
Policies on set-asides for renewables have changed over the past six years. In ER 90, the Energy Commission adopted a non-fossil set-aside as an interim solution to accomplish resource diversity, until the as-yet-unquantified benefits and costs were further analyzed, and a more efficient economic solution was available. In ER 92, values were developed to reflect the air quality benefits of renewables, and diversity benefits were examined using portfolio theory and decision analysis. The analysis indicated that diversity benefits were small. However, ER 92 also indicated that the renewables benefits analysis was not yet definitive and, therefore, continued a set-aside policy on a smaller scale than in ER 90.

In ER 94, alternative methods of achieving diversity goals were examined, including a diversity set-aside as well as a competitive market option, more consistent with the movement in the electricity industry towards a more competitive and less regulated and planned market. The Energy Commission continued to support diversity goals, and to support a set-aside in the event of a regulated resource procurement auction (deemed unlikely), but also strongly recommended that the Legislature amend diversity requirements to recognize the need for market-based incentives rather than government-controlled resource planning and procurement processes.

The only auction that was held, based upon the ER 90 integrated assessment of need, was substantially delayed and the results were eventually thrown out by the Federal Energy Regulatory Commission (FERC) because the CPUC limited participation to Qualifying Facilities. FERC found that this excluded substantial amounts of low-cost power and, therefore, the results of the auction did not meet its definition of "avoided cost."
Without FERC's approval, no utility could be forced to sign power sales agreements under penalty of federal sanctions, although the CPUC could have imposed this requirement under its own authority. It chose not to, in anticipation of electricity restructuring.

AB 1890 Renewables Policy

In contrast, ER 94 (used as the base case for the projections below) included the results of the BRPU as committed supply resources, including 500 MW of planned additional renewable capacity, largely geothermal and wind plants, but none of these plants were constructed prior to the auction's rejection by FERC. No new procurement auctions of this type are likely in the restructured electricity industry. Consequently, the ER 94 analysis included prospective renewable resources that were unlikely to be built as planned without alternative renewable policies.

In addition, the ER 94 analysis did not reflect any potential loss of existing renewable resources as a result of increased competition in a restructured electricity industry
and of reduced revenue as existing contracts pass the fixed-energy portion of their standard offer contracts. Consequently, AB 1890 policies act primarily to take the place of, rather than supplement, the base case (ER 94) renewables additions. The rejection of BRPU results, and the competitive impact of restructuring, would ordinarily cause reductions in the amount of renewable power in California; however, policies established under AB 1890 should act to return the amount of renewables in the resource mix to near the base-case levels. Table IV.5-4 shows a comparison of estimated available peak capacity from renewable resources in the base case, in comparison to the BRPU/Competition case and the case with AB 1890 policies.

Table IV.5-4: California's Renewable Resource Projections (Estimated Available Peak Capacity)

Renewable Resource	1994 Existing (MW)	2005 Base Case - ER 94 (MW)	2005 Competition, No BRPU (MW)	2005 Including AB 1890 policies (MW)
Geothermal	1610	1490	1160	1490
Wind	330	640	210	570
Biomass	940	970	620	910
Solar	370	370	190	410
Small Hydro	50	60	50	60
*Totals	3300	3520	2240	3440

*May not reflect resource sums due to rounding

Renewable policies in California have been based upon issues such as the diversity of the resource mix, energy security, local air quality and, in recent years, global climate change concerns. These policies have fostered significant growth and diversity in renewable power generation in the state. California's policies have not been established solely to deal with GHG concerns, and renewable power sources fostered in California will have a wide variety of impacts on GHGs.

Generally, renewable resources can be said to be preferable to traditional fossil fuels, based solely on CO_2 emissions reductions from electricity generation. However, in specific cases, a number of factors can alter these results. The type of renewable generation, alternative uses for the fuel that may be used as renewable feedstocks, and the manner in which the electricity system and other emission impacts are modelled all affect this conclusion. What can be said is that, for purposes of GHG emissions-reduction strategies, some types of renewable power are preferable to others. There are also circumstances in which some renewable facilities may actually increase GHGs, when compared to displaced conventional power. Without considering cost-effectiveness or a variety of potential system interactions and non-electricity system impacts, the various renewable options can generally be ranked (based primarily on combustion-produced CO_2 emissions) as follows:

Rank

1 Non-GHG Emission Producers

Wind, hydro, photovoltaics, nuclear, non-gas solar, liquid geothermal (with gas injection)

2 Minor GHG Emission Producers

Gas-assisted solar (no more than 25 percent gas burn)
Steam geothermal
Biomass (feedstock combusted alternatively)
Landfill gas (feedstock flared or combusted alternatively)
Municipal Solid Waste (MSW) (avoided methane flared or combusted alternatively)

3 Others

Other Biomass
Landfill Gas
Fuel cells
MSW
Conventional natural gas plants (boilers)

In comparison, advanced natural gas powerplants would fall between Ranks 2 and 3, above. Older gas plants are probably closer to Rank 3, and coal and oil-fired facilities below Rank 3. An analysis that factors in cost-effectiveness, extending to societal cost/benefits, would be critical in developing a more accurate ranking of renewable energy supply options with regard to GHG emissions effects, as well as an understanding whether particular renewable policies would be cost-effective.

While the Energy Commission believes that the renewable resources resulting from recent policies adopted under AB 1890 will tend to reduce GHGs, there will likely be little reduction from the base, ER 1994 case. In general, nurturing the growth of renewable resources in California remains a reasonable GHG-reduction strategy, but consideration must be given to the varying impacts of different renewable resource technologies and their respective costs.

Conclusions

1. Under restructuring, the level of renewable resources used in the electric generation sector will not differ substantially from renewables additions planned by the utilities in 1994. A comparison of projected available peak capacity for the year 2005 from renewable resources in the 1994 base case (based upon resources planned under regulatory proceedings) shows a total of 3,520 MW, while the case with AB 1890 policies shows a total of 3,440 MW (see Table IV.3-4, Chapter IV).

2. While nurturing the growth of renewable resources in California remains a strong GHG-reduction strategy, consideration must be given to the varying emissions impacts and the respective costs of different types of renewable resource technologies when supporting their use.

3. Generally, renewable resources can be said to be preferable to traditional fossil fuels, based solely on CO_2 emissions reductions from electricity generation; however, on a more specific level, a number of factors can alter these results.

4. The Energy Commission will continue to evaluate the impacts of renewable resource additions on reducing GHGs in California. An analysis that factors in cost-effectiveness, extending to societal cost/benefits, will be undertaken to develop a more accurate ranking of renewable energy supply options with regard to GHG emissions effects.

Section IV.1 Appendix A: Models used for Energy Efficiency Scenarios

The model for the 1994 Constant Funding Scenario was developed in 1994 using methods and models that traditionally furnish resource forecasts for the Energy Commission's Electricity Report process.[39] The Energy Commission ultimately adopted forecasts of electricity use that included staff's recommended modifications to utility forecasts of energy savings from their programs. For the other two scenarios (1996 Constant Funding and Decline After 2002) two new models were used in 1996 to independently estimate the potential energy savings that might occur.

The first model, DSM Energy Resource Assessment Methodology (DENRAM), estimates energy savings from programs in gigawatt hours of electricity and millions of therms of natural gas. The model presumes that the reductions in CO_2 emissions will correlate with the savings from energy efficiency programs. The ratios of funding to initial energy savings for these programs are similar to those used to assess the effects of historical utility-managed programs in the Staff's ER 96 electricity forecast.[40] For the 1996 Constant Funding Scenario, Staff estimated greater long-term persistence characteristics (i.e. market transformation effects) for future programs by designing the "duration curves" component of the DENRAM model to include a modest "spillover" effect. Traditional duration curves used to model the effects of historical programs in Staff's ER 96 demand forecast (and also in the Decline After 2002 Scenario), presume that savings from programs decay more rapidly over a shorter time period.[41]

For each scenario, seventy five percent of the total impacts from programs is presumed to occur in residential and commercial customer sectors. This inference was based on actual energy efficiency program budgets from utilities in 1994 and 1995.

The other model used to develop data for the 1996 Continuous Funding Scenario and for the Decline After 2002 Scenario was the California DSM Resource Assessment Model (CALRAM). It provides related information on measures likely to produce the energy savings identified by DENRAM. CALRAM is a technology-based model that uses economic cost effective screens and pre-specified technology saturation targets, based on actual utility program experience, to derive assumed levels of annual technology installation and associated load impacts. CALRAM inputs include levelized measure and marginal costs, useful lifetimes, penetration rates, measure and technology savings data from the California Conservation Inventory Group's Database for Energy Efficient Resources[42] and other disaggregated features to suggest measures that will provide the majority energy savings or will disappear as energy efficiency reverts to free market conditions. In brief, the first model, DENRAM, estimated total load impacts in energy savings and CO_2 emissions, while CALRAM showed specific technologies and end uses that are likely to provide most of the savings.

ENDNOTES

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1 Average (64 percent to 66 percent) based on share of total demand represented by residential and commercial customers for 1995 to 2010 per Energy Commission Staff ER 96 electricity demand forecast (March 27, 1996).

2 The 1994 Constant Funding scenario is from the forecast of future energy efficiency program effects, entitled the "Status Quo Case" from CEC Staff's "Supplement to October 5, 1994 Staff Testimony on Powerplant Resource Assessment for the Five Largest Utilities", docket No. 93-34-94, October 26, 1994.

3 The actual expenditures and savings for programs in 1995 was used in both of these new scenarios.

4 The 1996 Constant Funding Scenario is based on the "Business as Usual Case" in the CEC staff, "Revised Report on Uncommitted Energy Efficiency Forecasts: Preliminary Testimony for the June 11th, 1996 ER '96 Committee Hearing," May 17, 1996.

5 Electricity expenditures for residential and commercial customers and gas expenditures are estimated from Advice Letters filed in October 1996 by investor owned utilities with the CPUC and from Staff historical estimates of expenditure for LADWP and SMUD.

6 The original development of the Decline after 2002 Scenario is contained in the CEC Staff unpublished draft report, "Uncommitted DSM Electrical Impacts with Expenditures Decaying After AB 1890's Mandated Levels," December 19, 1996.

7 Gas demand for the commercial and residential sectors is from CEC Staff's 1995 Natural Gas Market Outlook, Pub. No. P300-95-017A, page b-5, "1995 Fuels Report Base Case," October, 1995. Conversion presumes 1040 Btu/cubit foot of natural gas.

8 See CEC Staff, "Appendix A of the 1994 Electricity Report (ER 94) Electricity Supply Assumptions Report (ESPAR): Part I: Electricity System Assumptions: Section C (A-I-C): ER 94 Forecast of Uncommitted Demand-Side Management (DSM), (November 1994); and for details by customer class see: CEC Staff, "Supplement to October 5, 1994 Staff Testimony on Powerplant Resource Assessment for the Five Largest Utilities" Docket No. 93-ER-94 (October 26, 1994), Form BC-2 (various pages).

9 These models are described in the "Models Used" attachment to this section.

10 CEC Staff, Appendix A, pp. A-I-C-3 to A-I-C-11.

11 Investor owned utilities estimates from PGE, SCE, and SDGE Annual DSM Reports filed with the CPUC in 1996; LADWP and SMUD expenditures are based on historical data.

12 This equivalence agrees with ratios that CEC ERAO staff developed in 1993; see Douglas Herr, CEC Staff to David Niesenbaum, Dept. of General Services, Letter (February 2, 1993). CEC Staff conversation, Dennis Smith and James Hoffsis regarding recent work in support of CEC Biomass review project (January 1997).

13 Perry Lindstrom, Dept. of Energy (EIA) to AESP-Net@AESP.org, e-mail "New Carbon Calculation" (January 23, 1997). Suggests a rate of 573,300 lbs/GWh based on 1995 nationwide data.

14 Referred to in e-mail from Jim Hoffsis to Lynn Marshal, "Question from BAAQMD" (July 29, 1996).

15 Data on operations was obtained from unpublished measure retention reports of SDGE, PG&E and SCE submitted in January 1997 to members of the CADMAC Energy Persistence Subcommittee.

16 Data on PG&E's residential programs was not available.

[17]PG&E, *1996 Annual Earnings Assessment Proceeding,* Appendix A “Annual Summary Report on Demand Side Management Programs in 1995 and 1996" (April 1996); SDGE, *Demand-Side Management Programs* (May 1996); SoCal Gas, *Demand-Side Management Annual Program Summary Report* (April 1996).

[18]The "spillover curve" for the 1996 Constant Funding Scenario after 1997 and the "decay" curve for the 1996 Constant Funding Scenario to 1998 and for the Decline After 2002 Scenario for all years. The persistence curve is discussed in CEC "Staff Revised Report" *op. cit.*, pp. 20-22.

[19]Forecast gas demand for the commercial and residential sectors is from CEC Staff *1995 Natural Gas Market Outlook* (October 1995) Pub. no. P300-95-017A, page b-5, "1995 Fuels Report Base Case". Conversion presumes 1040 Btu/cubic foot of natural gas.

[20]Conversion factor from therms to carbon is from Tables 5-8 and 5-9 of CEC, *Global Climate Change: Potential Impacts & Policy Recommendations: Volume II* (December 1991), pub. #P500-91-007VII, pages 5-42 and 5-43.

[21]The row in Table 1 "1994 Constant Funding" and the row in Table 4 "No Programs" are combined, although there is no equivalent to the "1994 Constant Funding" data series for natural gas demand.

[22]California Department of Conservation, Division of Oil, Gas and Geothermal Resources, communication with staff, June, 1997.

[23]Staff communication, June, 1997.

[24]Environmental externalities are environmental damages resulting from the construction or operation of a facility that the owner does not need to consider controlling because the damages are unrecognized or unregulated, e.g., CO_2 emissions. The damages and their control costs are “external” to the owner’s decision making.

[25]Public Utilities Code section 701.1(c) which applies to the California Public Utilities Commission: “In calculating the cost effectiveness of energy resources, including conservation and load management options, the commission shall include, in addition to other ratepayer protection objectives, a value for any costs and benefits to the environment, including air quality.”

[26]Public Resources sources Code section 25000.1(c) which applies to the Energy Commission: “In calculating the cost effectiveness of energy resources, including conservation and load management options, the commission shall include a value for any costs and benefits to the environment, including air quality.”

[27]In both *ER 92* and *ER 94*, the [Energy] Commission has researched land and water externalities, surveying economic literature including Bonneville Power Administration, New York State Public Service Commission and Electric Power Research Institute studies. These studies indicate that land and water externalities tend to be small in comparison to air quality externalities (except for hydro resources. In part, this may be because the process of developing generation options for capacity expansion analysis implicitly screens out some options precisely due to land and water externality problems.” ER 94, Chapter 3, endnote 5, page 65.

[28]Nitrogen Oxides (NO_x), Sulfur Dioxide (SO_2), Carbon Monoxide (CO), Reactive Organic Gases (ROG), and Particulate Matter 10 microns or smaller (PM_{10}).

[29]Because of the underlying assumptions and methodology used to estimate residual emissions costs, the costs, except for CO_2, may only be applied correctly to emissions from existing power plants.

[30]These utilities are Pacific Gas and Electric, Southern California Edison Company, San Diego Gas and Electric Company, and Los Angeles Department of Water and Power. A social cost analysis was not conducted for the Sacramento Municipal Utility District.

[31]Private costs are the net present value of the future stream of annual capital, fuel, variable and fixed operations and maintenance, offset and marketable emission credit costs; the costs of any power purchase contracts; and the generating system's value, applied to resource additions when it is above its reserve margin target.

[32]Social costs are private costs plus the net present value of the future stream of annual externality costs of the residual emissions from powerplants.

[33]The planning period for *ER 94's* analyses stretches from 1994 through 2013. However, the Energy Commission's analyses tend to focus on the first 8 to 12 years of the planning period because the California Public Utilities Commission' Biennial Resource Plan Update awards power purchase agreements only to powerplant additions found to be cost-effective during that period. Furthermore, resource additions in the later years have more of their benefits and costs calculated in the "end effects" period after the production cost simulation ends. Thus, any finding of cost-effectiveness after the 12th year is generally not considered to be significant.

[34]In order to compare "apples with apples" the emissions of the fully built-out private cost case system were assigned residual emission values.

[35]The minimum offset ratio for moderate non-attainment areas is 1.15:1, for serious 1.2:1, for severe 1.3:1, and 1.5:1 for extreme. In severe non-attainment areas, an offset ratio of 1.2:1 may apply if best available control technology is required for all existing volatile organic compound sources. In extreme non-attainment areas, an offset ratio of 1.3:1 may apply if offsets are obtained from internal sources.

[36]In reality since offset requirements are greater than one and are calculated based on the source's maximum ability pollute, an offset-purchasing fossil-fired powerplant causes a net area reduction in the residual emissions for which it must purchase offsets. In *ER 94*, such an occurrence was ruled out. Powerplants purchasing offsets could only net area residual emissions to zero.

[37]Avoided energy costs are estimates of the utilities' energy procurement costs that would have been incurred were it not for the energy provided under the contracts.

[38]Fixed capacity payments are provided in SO2 and ISO4 contracts for the life of the contract, which is often as much as 30 years.

[39]See CEC Staff, "Appendix A of the 1994 Electricity Report (ER 94) Electricity Supply Assumptions Report (ESPAR): Part I: Electricity System Assumptions: Section C (A-I-C): ER 94 Forecast of Uncommitted Demand-Side Management (DSM), (November 1994); and for details by customer class see: CEC Staff, "Supplement to October 5, 1994 Staff Testimony on Powerplant Resource Assessment for the Five Largest Utilities" Docket No. 93-ER-94 (October 26, 1994), Form BC-2 (various pages).

[40]Historical and committed DSM effects model is described in CEC Staff, *California Energy Demand: 1995-2015 Volume XI: Committed Demand Side Management Program Savings* (July 1995), publication number P300-95-0014.

[41]Ibid., page 22.

[42]California Conservation Inventory Group and the California Energy Commission, *Database for Energy Efficient Resources, Version 4.0* (April 3, 1996), $99.00 California Energy Commission, (916) 654-5200.

CHAPTER V

Reducing Greenhouse Gas Emissions From Forestry, Livestock and Solid Waste

Introduction

Strategies to reduce GHGs, primarily CO_2 and methane, from sectors of the economy other than the energy sector are further evaluated in this chapter. They include improvements in:

1. Forestry Management for Carbon Sequestration;
2. Livestock Management for Methane Emissions Reductions; and,
3. Solid Waste Management for Methane and CO_2 Reductions.

The Energy Commission developed inventories of GHG emissions from these sectors and consulted with the California Department of Forestry and Fire Protection (DFFP) and the Integrated Waste Management Board (IWMB) with regard to current policies and programs in response to numerous issues, including improvements in forest practices, urban forestry management, agroforestry/biomass development, livestock methane emissions capture and use, irrigation water problems, waste prevention and recycling. Programs designed to address these issues can concurrently reduce GHG emissions in these sectors. Since the draft of this report was issued, in November, 1997, the Energy Commission is also assisting the IWMB in acquiring EPA funding for local and regional entities in California to carry out projects specifically designed to reduce GHGs resulting from solid waste management practices. The following sections describe emissions of greenhouse gases from these the forestry, livestock and solid waste management sectors and discuss strategies that assist in reducing GHG emissions.

V. 1. Forestry Management for Carbon Sequestration and Emissions Reductions

Forests are complex ecosystems with several interrelated components, each of which removes carbon from the atmosphere and stores it in a process known as carbon sequestration. Carbon sequestration is a two-step process: carbon dioxide is withdrawn from the atmosphere through photosynthesis, and then is stored in organic materials over a period of time. The sequestration process ends when carbon is released back to the atmosphere as carbon dioxide, through combustion or decay processes. Carbon sequestration is therefore defined by net flows of carbon between forests and the atmosphere. Carbon sequestration in forests increases when the amount of carbon withdrawn from the atmosphere exceeds the release of carbon to the atmosphere. Given concerns about the reduction of forested areas on the planet, largely due to human activities, which is amplifying the effects of CO_2 on global climate changes, it is wise to pay attention to the CO_2 sequestration benefits of improved forestry management practices. This section reviews forestry-related emissions reduction strategies proposed in the *1991 GCC Report* and presents the current status of strategies to reduce atmospheric CO_2.

The California Department of Forestry and Fire Protection's (DFFP) Forest and Range Resources Assessment Program staff has studied the issue of carbon sequestration over many years and developed the strategies discussed below. It is important to note that this information is not yet departmental policy, but is part of ongoing strategy discussions that have been under consideration by the department since 1990. Strategies under discussion include:

1. Implementing policies and institutional changes related to the management of wildlands that will enhance the sequestering of carbon, including expanding and improving the California Forest Incentive Program;

2. Further developing Agroforestry/Biomass Energy Programs; and,

3. Devising and instituting new strategies to replace current urban tree planting programs.

California Forest Incentive Program

The California Forest Incentive Program has provided cost-share incentives to nonindustrial private forest landowners who carry out reforestation, timber stand improvement or wildlife enhancement projects. Eligible landowners must own less than 5,000 acres of timberland and agree to hold their land for timber production for ten years after completion of the project; they cannot use the land to meet the restocking requirements of logged areas under the Forest Practices Act. This program has been administered by the DFFP and funded by receipts from timber sales on the Department's Demonstration State Forests. In 1996, the California Department of Finance redirected funds allocated to this program to inspection and enforcement of reforestation projects, so the program is currently unfunded. A number of proposals have been made to plant trees as a method of removing CO_2 from the atmosphere. The following analysis is developed around the tree-planting concept to define the costs and carbon benefits of such an effort.

There are currently 945,000 acres of understocked or nonstocked timberland in California. These lands are primarily lower-quality lands, throughout the state, which have not naturally regenerated following disturbances due to severe climatic conditions. While carbon sequestering rates for whole forests as high as 12,000 lbs. of carbon per acre per year have been estimated by some scientists for mesic tropical forests, a realistic estimate for these marginal California lands is 500 to 600 pounds of carbon per acre per year. About 73 percent of this carbon would be in the bole of the tree and removed during harvesting of timber, primarily for building construction; this amount would be assumed to be stored carbon. The remaining 17 percent of timber would be used for various purposes, such as paper and energy production, which effectively return the carbon to the atmosphere. However, the anticipated 73 percent of stored carbon can be raised to about 75 percent, since these lands are currently covered with vegetation that varies from grass to heavy brush to multi-storied stands of low-density conifer trees.

Conversion to fully-stocked forests would, therefore, only net a long-term steady state of (conservatively) about 300 pounds of carbon per acre, annually. The costs for tree planting on these difficult sites range from $250 to $525/acre, depending on what type of site preparation and follow-up treatments must be made to maintain the trees. Using an average of $350/acre and 300 lbs. carbon/acre/year, 284 million pounds of carbon could be sequestered annually on a perpetual basis, at an initial cost of $331 million, spent over a 15 to 20 year period of initial reforestation.

Little research has been done on the basic genetics and genetic diversity of many of the state's native trees. This information is vital in order to know which species to select and make available for reforestation in a changing climate. In conjunction with the genetic research, progeny testing of many California species spread over a wide range must be initiated. This information will allow selection of families of trees that are adapted to the changes in climate. The current Forest Practices Act very narrowly defines which species can be used for reforestation following timber harvesting. In the face of a changing climate, considerably more flexibility must be allowed to select stock that can survive to maturity.

Conclusions

In order to accomplish such a reforestation task, the following policy and programmatic issues need to be addressed:

1. Develop methods to induce private landowners to participate and to hold their land in timber production for a period of time much longer than the current 10 years.

2. Revise tax policies to give both the industrial and nonindustrial forest landowner an incentive to plant trees.

3. Remove restrictions in the current program to allow cost sharing for planting a wider range of species and for a wider range of purposes.

4. Revise the reforestation delivery system that uses specialists with a single purpose.

5. Revise the current federal and state programs that deal with tree planting, in order to provide for a coordinated effort.

6. Develop programs which will allow the state to respond to changes in the climate, and to maintain viable forests and a successful forest products industry.

Further Strategies for Reducing CO_2

Development of more effective waste collection processes and urban forestry management are extremely effective ways to reduce CO_2 in the atmosphere, and generate significant additional environmental benefits. Improved waste collection and use from both wildland and through agroforestry practices can produce renewable, biomass-based energy resources and reduce landfills. Improved urban forestry practices could both reduce CO_2 production and benefit energy conservation. In order to reap such potential benefits, the following strategies should be considered:

Biomass Energy Programs and Agroforestry

Vegetation Management Program Enhancement

The Vegetation Management Program currently carries out fuel reduction through the use of fire and mechanical removal. Both of these activities result in releasing stored carbon to the atmosphere. However, in view of the changing climate's relatively rapid increase in dead fuel loads, and the concomitant increased probability of large destructive fires, the program would have a net positive benefit if the emphasis shifted to fuels collection for biomass energy production. Biomass fuel harvesting from our wildlands has been investigated and evaluated in the past. For example, a mobile unit which could harvest brush and pelletize the material for use as fuel feed stock has already been developed in a pilot project. Such a system would be an effective alternative to burning brush-covered lands for fire hazard reduction. Since the potential climate change would likely increase the number and extent of fires, multiple objectives could be met with such a program.

Expanded Agroforestry/Biomass Development

Agroforestry, i.e., the growing of trees on lands normally used for irrigated agriculture, has recently been used to deal with irrigation run-off water problems in the southern San Joaquin Valley. This effort, if coupled with the development of biomass energy generating plants, can provide a cost effective, and carbon neutral, energy production system.

In the last several years, one timber company has made major investments in growing eucalyptus on marginal range land using drip irrigation. Eucalyptus has unique fiber which is very important in the production of paper. Previously, the company imported Eucalyptus pulp from South America. While paper is generally only a short-term carbon sink, the opportunity to develop expanded markets for private producers of tree biomass may, in fact, induce considerably more activity in the growing of trees on marginal agricultural and range lands.

Municipal wastewater could be used for the production of biomass for energy production. While the use of such water on agricultural crops has met with some resistance, it would appear that its use on tree crops could produce large volumes of biomass. In planting trials with species such as Casurina, a salt-tolerant species from Australia, growth rates exceeding 10 feet in two years have been observed. Projecting 1980 effluent data to the present, it appears that about 8 million acre feet of wastewater would be available. This could easily translate into 1 to 2 million acres of trees, depending on the availability of space and irrigation rates.

Conclusions

The following actions would enhance carbon sequestration in the areas of agroforestry and biomass-to-energy production:

1. Reinstate a statewide biomass program to stimulate interest and investment in biomass production and use, through pilot projects, providing education and information and other mechanisms. Such a program must be multi-agency in order to bring together the combined interests, authorities, knowledge and ideas spread across several government agencies.

2. Investigate the feasibility and potential incentives necessary to require the use of wastewater for irrigation of biomass crops.

3. Provide financial incentives which will make the use of biomass an economically-viable alternative to other sources of fuel.

The Energy Commission's *Policy Report on AB 1890 Renewables Funding* to the Legislature, approved by the Legislature on October 12, 1997, recommended that 45 percent of the $540 million allocated under AB 1890 be directed toward funding existing (including currently non-operating) biomass and solar thermal projects, during the transition period to a fully market-based, competitive system for supplying renewable energy resources for California. This proposal is designed to enhance the transition of renewable energy resource suppliers to a free-market environment and to be responsive to specific legislative direction to support the operations of existing renewable technologies that provide fire suppression benefits, reduce landfill materials, and mitigate open-field agricultural burning. The strategies discussed above can add substantial support for these goals.

Urban Forestry Management

Current research indicates that an urban tree is 15 times more effective at reducing carbon dioxide production than a wildland tree. This effect is primarily due to reducing heat islands (such as unsheltered parking lots) in urban areas and associated reductions in air conditioning demand. The American Forestry Association's Global Releaf program is carried out in California in cooperation with the California Department of Forestry and Fire Protection. The objective is to plant 20,000,000 trees in California by the year 2000. There are 10,000,000 street and yard tree spaces currently available in California and 60,000 miles of state highways, on which 250 trees per mile could be planted.

There is a large, but unknown, amount of publicly-held land near or in urban centers. These lands are not parks, or necessarily designated green belts or open space, but are lands owned for other purposes. A local example is the land surrounding the Sacramento Regional Wastewater Treatment Plan. Such areas could be planted with trees, using public funds.

Conclusions

The following strategies would significantly enhance the planting of trees in the urban environment:

1. Require a tree planting and maintenance element in every local general plan.

2. Require all new school building activities to incorporate greenbelt tree plantings.

3. Mandate the inclusion of "tree space" in every land development.

4. Provide tax credits and other incentives to other utilities and energy producers to develop or expand urban tree planting programs in their service areas as an energy

conservation measure. Growth in these types of programs could be greatly encouraged through such measures.

5. Require planning for trees either individually or in green/shade belts in parking areas, which would ease the difficulty of planting after construction and increase the rate of growth and survival.

6. Develop a program to inventory the available publicly-held lands that could be planted with trees and provide incentives, such as cost sharing or other mechanisms.

V.2. Livestock Management for Methane Emissions Reductions

Introduction

This section reviews the strategies for reducing emissions from livestock proposed in the *1991 GCC Report*, data provided in the *1990* and *Historical and Forecasted Greenhouse Gas Emissions Inventories*, and the current status of the emissions reduction strategies and their costs. The emissions reduction strategies identified promoted research, development demonstration and evaluation of the effectiveness of the major technologies capable of converting methane emissions into a useful energy source and considerably reducing the contribution of these emissions to global climate change.

Methane emissions are generated by the digestive process of domesticated animals and from related manure management practices. On an average annual basis, livestock accounted for approximately 680,000 tons or 35 percent of the total methane released to the atmosphere between 1990 and 1994. From 1995 to 2010, emissions from this source are expected to be approximately 700,000 tons annually. This is the second largest source of methane emissions in California -- landfill gas being first at approximately 1,000,000 tons per year, or 50 percent of total methane released; however, unlike landfill gas, methane emissions from livestock are not typically captured or controlled in any way.

Approximately 33 percent of the manure produced in 1989 was sold as fertilizer and had a market value of $20 million,[1] and approximately 2 percent was burned directly for energy recovery. The remaining manure was handled through various management practices. The majority of all the cattle in California, 52 percent, are raised in three counties in the San Joaquin Valley: Fresno, Tulare and Merced. A substantial number of cattle are also raised in the Sacramento Valley and the Southeast Desert.

Historic Methane Emissions: 1990 to 1994

The California Greenhouse Gas Emissions Inventory includes historic methane emissions from 1990 to 1994, with a projection to 2010. The domesticated animals included are cattle, sheep, horses, hogs, pigs, goats, mules and asses. Cattle produce 97 percent of the methane from digestion and 75 percent of the methane from manure management. Table V.2-1 shows the methane emissions from livestock in California from 1990 through 1994.

Table V.2-1
Historic Livestock Methane Emissions
1990 - 1994
(Tons of Methane)

	1990	**1991**	**1992**	**1993**	**1994**
Digestive	406,500	388,000	386,000	385,000	385,000
Manure	290,626	297,381	299,108	298,489	301,093
Total	697,126	685,381	685,108	683,489	686,093

From 1990 to 1994 there was a slight downward trend in the cattle population (specifically of mature beef cows and bulls), which resulted in a drop in methane from digestion. In this same time period, anaerobic lagooning increased as a manure management practice, resulting in higher methane emissions. Taking these two opposing factors into consideration, Table 1 shows that there is no significant amount of change in methane emissions from livestock from 1990 to 1994.

Forecasted Methane Emissions: 1995 to 2010

A true forecast of domesticated animal populations is not available at this time. A forecast of the overall agricultural sector predicts that there will be no significant changes in animal populations from 1985 to 2010.[2] The California Greenhouse Gas Emissions Inventory used an average annual animal population from 1985 to 1994 to represent the forecast for 1995 through 2010. The resulting methane emissions are shown in Table V.2-2.

Table V.2-2
Forecasted Livestock Methane Emissions
1995 - 2010
(Tons of Methane)

	1995 - 2010
Digestive	397,000
Manure	302,458
Total	699,458

Methane Emissions Reduction Strategies

The two major emission reduction strategies originally presented in the *1991 GCC Report* were to

1) encourage the recovery and collection of methane from livestock waste. This could be achieved through continued efforts by the Energy Commission to support research, development, demonstration and evaluation of technologies capable of effectively recovering and using methane generated from livestock and other organic waste; and,

2) to evaluate differing methane recovery systems, through the Energy Commission's Energy Technology Advancement Program, to determine their effectiveness in reducing methane emissions.

Current Status of Strategies

Several anaerobic fermentation projects were evaluated as part of the California Energy Commission's Biomass Demonstration Program. At the Fat City Feedlot in Gonzales, California, cattle manure is slurred and pumped into a fermenter with a 15-day hold time. The biogas produced is combined with natural gas and burned in a steam boiler.

At the Marindale Dairy in Novato, California, cow manure is slurried and fed into a plug flow reactor. The biogas produced is used to fire a 40 kilowatt electric generator. At a similar project at Royal Farms No. 1 in Tulare, California, manure is slurred and sent to a covered lagoon for biogas generation. The collected biogas fuels a 70 kW electric generator.
Other methane generation facilities that have come on-line include a 130 kW unit at Cal Poly; a 500 kW unit for the City of Turlock; and a 1,500 kW unit for the City of Oxnard.

Based on an escalation rate plus annual inflation rate of 5.2 percent, a cash flow analysis indicates that the levelized cost for biogas anaerobic fermentation technology ranges from 3.9 to 8.7 cents/kWh in real 1997 dollars. This technology has a heat rate ranging from 15,000 to 20,000 Btu/kWh. This equates to a levelized cost ranging from \$2.60 - \$4.35/MMBtu.

Effects on Greenhouse Gas Emissions

Approximately 75 percent of the methane emissions from manure management come from anaerobic lagoons. If these emissions can be captured as demonstrated by the technology discussed above, then the methane emissions from manure management can be reduced from approximately 300,000 tons to 72,000 tons, annually. The combustion of this much methane would result in a CO_2 emission of approximately 660,000 tons. Taking into account the fact that methane is 21 times as destructive as CO_2, we have a net greenhouse gas emission reduction of approximately 197.6 thousand tons of methane.

Forecast Based on Emissions Reduction Options

Taking the CO_2 emissions into account, Table V.2-3 shows the forecasted methane emissions from livestock with the appropriate emission reduction technology in place. This forecast does not take into account the possibility that this fuel could be used to generate electricity, reducing the need to produce electricity by some other means. Also, this forecast does not consider the possibility that this fuel could be used to produce steam that would otherwise have to be produced by some other means. However, in both cases this displacement of steam/electric generation is going to be small, and in the case of electricity may actually prove to contain more emissions than traditional utility fuels.

Table V.2-3
Forecasted Livestock Methane Emissions
with Emission Reduction Technology
1995 - 2010
(Tons of Methane)

	1995 - 2010
Digestive	397,000
Manure	104,819
Total	501,819

Conclusions

The capture and use of methane emissions from anaerobic lagoons have the potential to reduce annual methane emissions from livestock by 197,639 tons. Methane has a heat content of 1,050 Btu/scf and a density of 0.042017 lbs/scf. Therefore, 197,639 tons of methane has 9,877,952 MMBtu of energy. At levelized costs of $2.60 - $4.35 cents/MMBtu, this option would cost from $25.7 to nearly $43 million to implement. The cost per ton of methane reduction would range from $130 - $217/ton. For this technology to be successful in this area, further work is required to develop, commercialize and package off-the-shelf systems for small-scale operations.

1. Further work is required to develop, commercialize and package off-the-shelf systems for small-scale anaerobic fermentation of manure to produce biogas.

2. The Energy Commission should continue to support research, development, demonstration and evaluation of technologies capable of effectively recovering and using methane generated from livestock and other organic waste.

V.3. Solid Waste Management for Methane/CO_2 Reductions

Introduction

The *1991 Global Climate Change Report* briefly discussed the contribution of municipal solid waste in landfills to GHG emissions from this source in 1990, and the effect of various recovery strategies on emissions, including flaring and conversion to substitute for natural gas, as either low or high-grade Btu gas. Landfill gas from the anaerobic decomposition of the organic waste in municipal solid waste (MSW) is composed primarily of methane (CH_4) and carbon dioxide, in equal parts. Landfills are the greatest single source of methane emissions in California, contributing about 42 percent in 1990, which is currently expected to rise to 64.4 percent by the year 2010. They contributed only a small amount of California's CO_2 emissions (less than 1 percent) in 1990.

Since that report was published, the U.S. EPA has issued final rules regulating municipal solid waste landfill gas emissions (New Source Performance Standards and Emissions Guidelines, March, 1996) for both new and existing landfills. California had acted even earlier, in 1989, to require solid waste management and gas collection practices that would, in order of priority, 1) reduce sources of emissions, 2) recycle and compost solid waste and, 3) transform or dispose of solid waste in landfills. California's Integrated Waste Management Act of 1989 set a target for the state's cities and counties of achieving a 25 percent landfill diversion rate by 1995 and a 50 percent diversion rate by the year 2000.

The technical appendix to this report[3] shows the methodology and results of the Energy Commission's analysis of baseline, current and forecasted methane and carbon emissions from municipal solid waste landfills, and a brief description and results are also presented in Figures V.3-2 and V.3-3, below. Forecasts are based on achievement of the targets set by the California Integrated Waste Management Act, as described. Further discussion in this chapter is on emission rate trends and strategies being undertaken in California and their potential to achieve state and federal goals.

Solid Waste Production and Management

The cycle of solid waste production is important to understand in assessing waste management practices. Virgin materials are harvested and converted into raw materials, causing greenhouse gas emissions due to energy consumption, fuel use, and changes in forest carbon sequestration. The conversion of raw materials into manufactured goods also uses energy, causing greenhouse gas emissions, but the actual use of manufactured goods produces almost no greenhouse gas emissions. Landfill gas is generated through various cycles of decomposition of waste by bacteria, with the final step being the breakdown of wastes by anaerobic bacteria that generate CH_4 and CO_2.

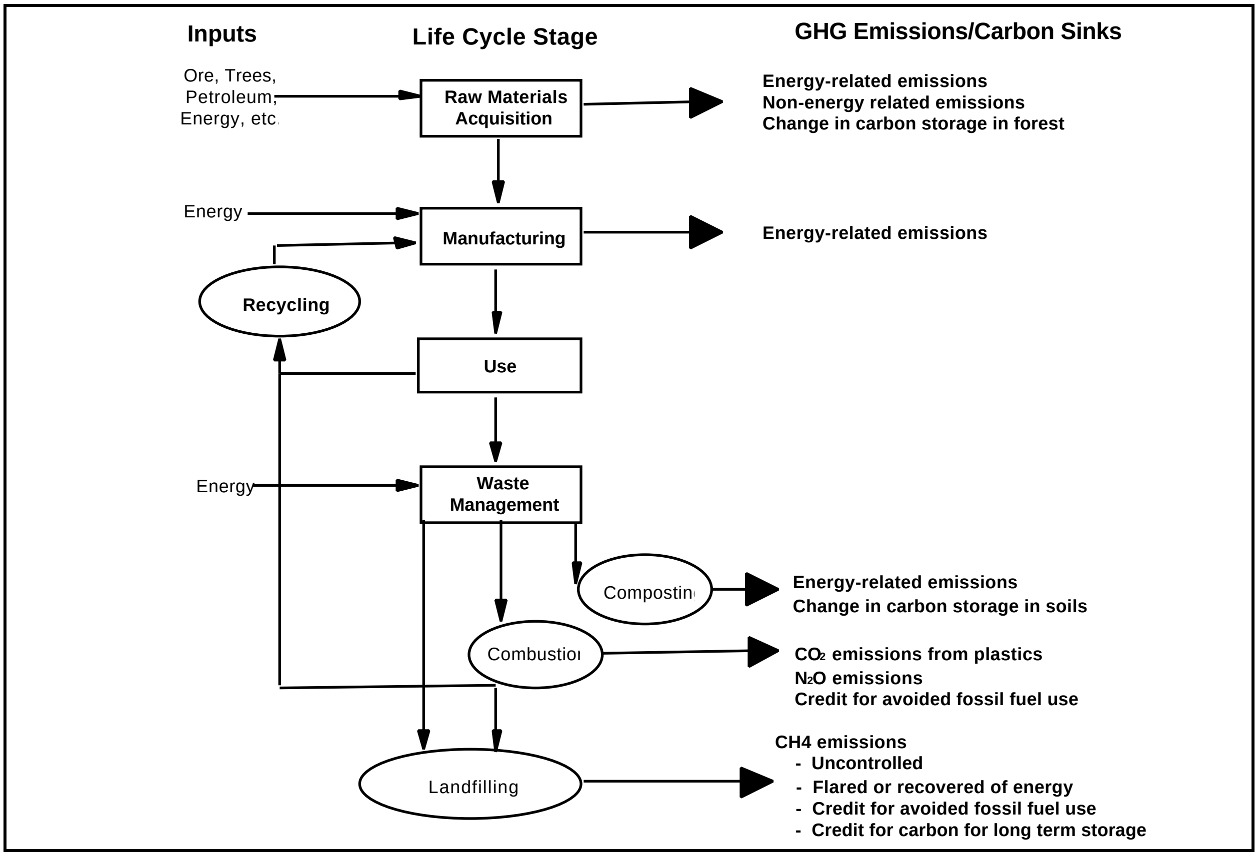
Solid waste management is a complex system of practices. Life cycle analysis of waste management practices, as illustrated in Figure V.3.1, is needed to identify the full impact on greenhouse gas emissions from changes in waste management practices. This analysis includes greenhouse gas emissions from raw materials acquisition and manufacturing, as well as recycling, composting, combustion and landfilling. The California Integrated Waste Management Board (CIWMB) has jurisdiction for effectively and efficiently developing and regulating the state's solid waste management practices. Waste management practices include landfilling, recycling, source reduction (not pictured), composting and burning (or combusting).

Landfilling is the ultimate destination for most manufactured goods. Landfill gas (LFG) is produced from the anaerobic decay of organic material in the landfill. LFG consists of 50% methane and 50% CO_2 by volume, making it combustible. LFG is collected (at about 80% efficiency) and is either flared or used for generating energy (either steam or electricity). Landfills are the leading source of anthropogenic methane emissions, but their impacts are partially offset by their "displacement" of electricity production as well as their carbon storage capabilities (e.g., plastics are considered sequestered carbon when in landfills).

Source reduction is the modification of a manufacturing process to use less raw material. Consequently, less virgin material is harvested and less processed material disposed of, and greenhouse gas emissions associated with harvesting, manufacturing, and waste management are avoided. Recycling involves the re-use of a manufactured item, or collecting it and re-manufacturing it into something else. Recycling creates greenhouse gas emissions in the collection phase, but avoids or reduces them in the harvesting and manufacturing phases, because less virgin materials need to be harvested. In some cases, recycled materials (e.g., aluminum) are easier to use in the manufacturing process.

Composting is the collection and processing of organic material, mainly grass and yard trimmings, into a soil additive. Composting diverts organic material from landfilling or combustion and, except for material collection emissions, has a positive impact on greenhouse gas emissions by sequestering carbon in the soil. Waste-to-energy (WTE) facilities either burn municipal solid waste (MSW) (combustion) or convert it into fuel pellets called refuse-derived fuels, and then landfill with recycled steel. WTE facilities produce greenhouse gas emissions, but also displace fossil fuel power production by using renewable energy resources, and increase steel recycling; the available space in landfills is increased by reducing MSW to ash, but no credit is given for these benefits.

Figure V.3-1



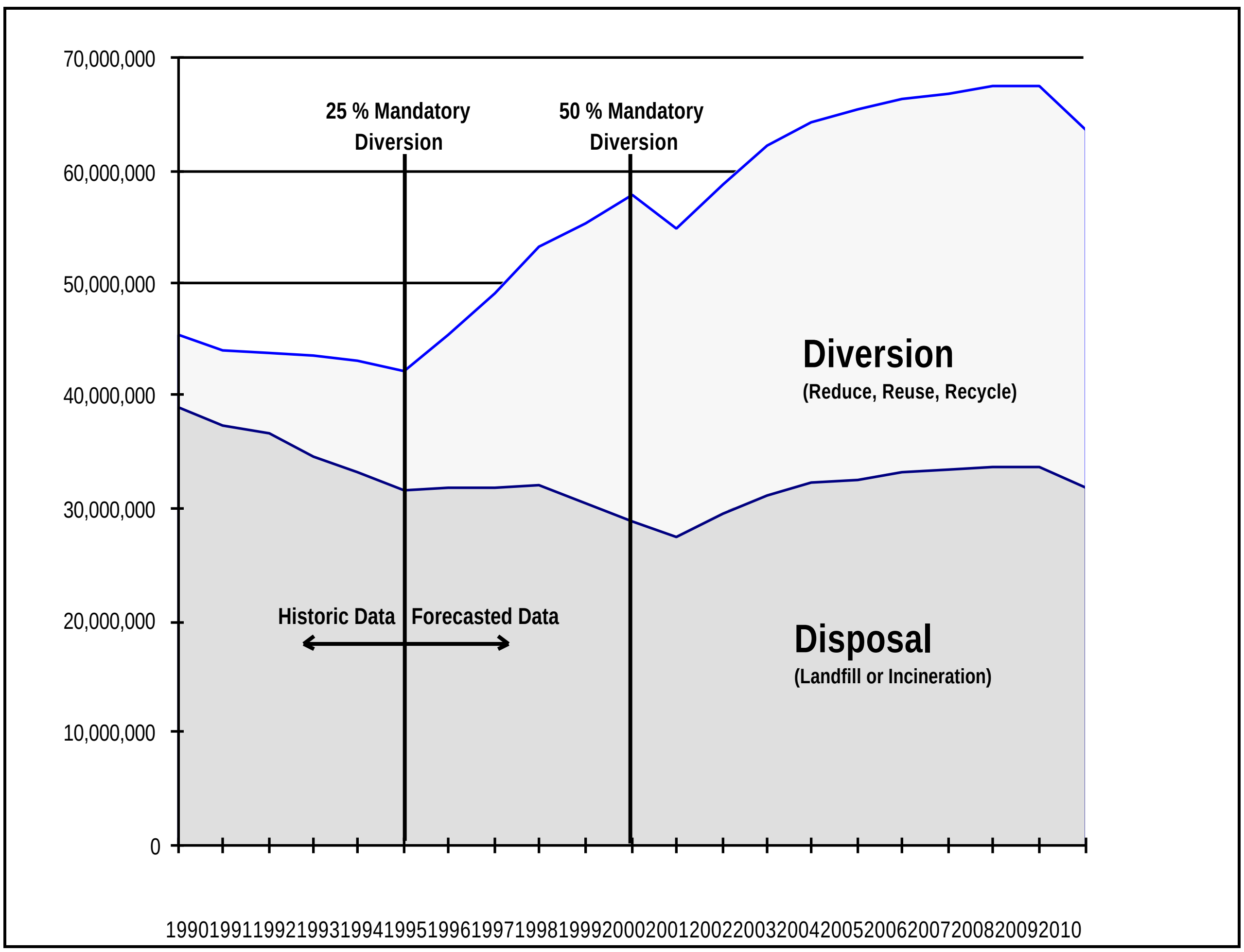
Greenhouse Gas Sources and Sinks
Associated with Municipal Solid Waste Management Practices

All of these practices, with the exception of source reduction, generate greenhouse gas emissions. However, some practices emit less than others by virtue of their effect on virgin resources, and by potentially receiving credits for producing electricity or steam.

Historic and Forecasted Annual Municipal Solid Waste: 1990 to 2010

According to California's Waste Management Act, by 1995 California cities and counties were to have achieved a 25 percent landfill diversion rate; this goal has been achieved.[4] By the year 2000, the target goal is a 50-percent landfill diversion rate. These diversion rates were incorporated into the forecast, as shown in Figure V.3-2, by assuming that reasonable progress would be made from 1995 to 2000. In other words, the 25-percent diversion rate was assumed to increase by 5 percent a year until 2000, when it would reach 50 percent diversion. From 2000 to 2010, the 50 percent diversion rate is held constant, while population and the economy continue to change. The diversion amount (actual tons) is calculated based on the 1990 MSW stream, with allowances for population[5] and changes in the local economy,[6] including employment, retail sales and home construction.

Figure V.3-2
Municipal Solid Waste Stream from 1990 to 2010



Municipal Solid Waste Emission Reduction Strategies

California Integrated Waste Management Board Programs

Activities and programs at the CIWMB wholly encompass most of the emission reduction options originally presented in the *1991 GCC Report*. The CIWMB programs described below are summarized from information received from the Integrated Waste Management Board.[7]

CIWMB programs include Waste Prevention, "Buy Recycled," Market Development, Used Oil and Household Hazardous Waste, Public Education, Research and Development, Planning and Local Assistance, Local Enforcement Agency, and Site Cleanup. The vast majority of programs are oriented towards waste prevention, recycling and education (both of the public and local decision makers). Programs also exist to assist local planning and enforcement agencies and support market development for recycled materials. Most of the CIWMB activities are complementary, such as activities of the Board's research and development program, as described in the Board's report, *Environmental Factors of Recycled Paper Manufacturing*, and the "Buy Recycled" Program, run by the Recycled Paper Coalition.

All of these programs have affected greenhouse gas emissions from waste management practices. The CIWMB has not only taken major steps to reach mandated recycling goals, but has also made California's solid waste management strategy one of the most effective in the nation. In addition to these programs, the California Energy Commission (CEC) has suggested upgrading landfill gas to substitute for pipeline-grade natural gas.

Rail-Hauling Out-of-State

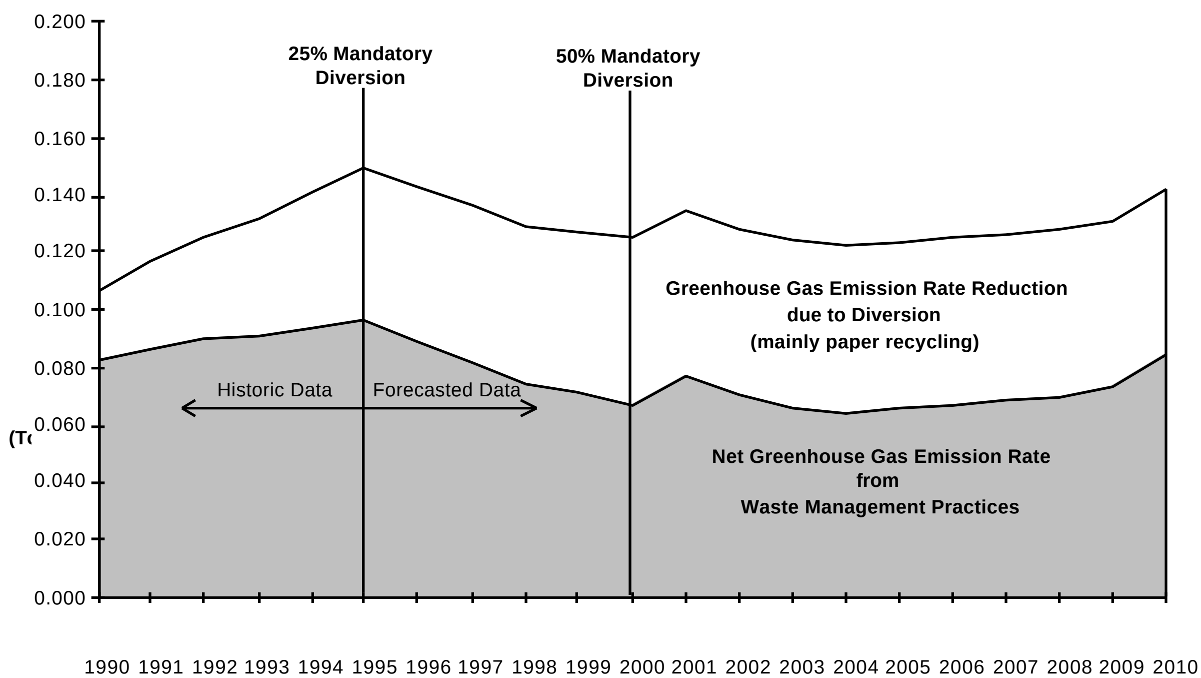
Rail-hauling waste out of the state, which removes a portion of the waste stream slated for disposal at California landfills, is a recent trend in waste management in California. Carbon emissions from the motive power of rail-hauling are negligible, compared to the landfill emissions. Currently, eight out-of-state rail-haul projects are either proposed or developed. No daily limits exist on the waste that can be accepted for most of the projects.

Napa County currently ships approximately 200,000 tons of MSW per year to Roosevelt Regional Landfill in southeast Washington.[8] If each of the eight projects could dispose of similar amounts, 1.6 million tons per year, or approximately 5 percent of the annual waste stream, could be disposed of, resulting in reducing methane (and methane equivalent) emissions from landfills by approximately 1.8 percent. If out-of-state landfills were to take the full amount of waste they can reasonably handle in a single day, all from California (approximately 5000 tons, or 14.6 million tons per year--about 45 percent of the California waste stream), methane emissions from California landfills could be reduced by 16 percent (reducing the waste stream by about 45 percent has only a 16 percent effect on methane emissions because the methane emissions from landfills are calculated based on the total waste currently in landfills, which is about 914 million tons; comparatively, 14.6 is only 1.6 percent of 914).

Carbon Emission Rate Changes from Solid Waste Management Strategies

Based on Environmental Protection Agency (EPA) Report 10, and the data from Figure V.3-2 on forecasted waste streams, Energy Commission staff has estimated the greenhouse gas emission rate trend shown in Figure V.3-3. It includes emissions from WTE and composting, but their contribution is not significant when compared to landfilling and recycling. Figure V.3-3 does not include source reduction measures, due to a lack of data; however, Figure

Figure V.3-3
Estimated Carbon Emission Rate due to Changing Solid Waste Management Practices



V.3-3 does show the effect that mandatory recycling targets will have on the carbon emission rate for the entire California Waste Management strategy, including indirect emissions (e.g., vehicular).

Unfortunately, the inventory on which EPA based its report does not match up well with the forecasted waste stream available from the CIWMB. For example, the California inventory does not include steel cans or the plastics category LDPE, which are included in the EPA study. Conversely, the EPA study did not include tire recycling/burning, which is included in California's Waste Management Strategy. Figure V.3-3 primarily represents the direct effects of paper and aluminum recycling on landfills, and indirect effects on virgin resources; however, because the majority of California waste management strategies are related to paper recycling,[9] Figure V.3-3 may still be an acceptable estimate of the carbon emission factor.

According to Energy Commission staff's analysis, annual methane emissions from landfills are forecasted to increase from 1.6 million tons to 1.8 million tons, from the year 2000 to 2010. According to the forecasted waste stream, the total annual waste generation (including that which is diverted) is increasing from 55 million tons to 68 million tons over the same timeframe. By converting the methane emission into an equivalent carbon emission, and dividing by total waste generation, an estimated carbon emission rate range from 0.17 to 0.15 tons carbon/ton MSW is acquired. According to Figure V.3-3, the average carbon emission rate for landfills (the net carbon emission rate, plus the carbon credit for diversion) is an average of 0.13 tons/ton MSW between 2000 and 2010. Because these two vastly different methodologies produce similar estimates, the net carbon emission rate shown in the figure appear acceptable.

Conclusions

Research by the CIWMB continues in many areas, including evaluating source reduction, market development, and uses for recycled materials. In using a wide array of management strategies, the CIWMB gives local California agencies options for responding to changing markets and trends in waste management. CIWMB has committed to positive, productive working relationships with key elements of the public and private sector and has established a successful record toward achieving mandated landfill diversion rates. The Energy Commission should continue to support the Waste Management Board in its efforts.

To determine the cost of any emissions reduction strategy it is necessary to identify the total impacts from all effects of that strategy. In waste management, changes in one strategy may substantially affect the results of other emissions reduction options.[10] Cost-effectiveness analyses should be carried out for the variety of strategies currently being implemented in managing municipal solid waste. The analyses undertaken in this report has lead to the following conclusions:

1. The Energy Commission will continue to support the CIWMB in its efforts to meet California's goal of 50 percent landfill diversion by 2000.

2. California state government should analyze the cost-effectiveness of a variety of strategies currently being implemented to manage municipal solid waste. A life-cycle cost analysis, similar to the analysis done by EPA on a national level, should be carried out to determine the costs and benefits associated with each solid waste management strategy California is undertaking.

3. Market analysis should be conducted to estimate revenues to California from the sale of marketable materials resulting from methane source reduction and recycling. This market analysis must, at the very least, be done for source reduction and recycling options. Additional market analyses should be done to determine the potential for electric generation from the combustion of municipal solid waste or landfill gas.

4. As a result of AB 1890, more biomass, municipal solid waste, and land-fill gas projects are expected to be built and be competitive in California's electric industry. The IWMB should continue to monitor criteria and GHG emissions from waste-based electricity production facilities, work with air quality agencies to reduce these emissions, and develop methods to ensure that those who produce waste materials, or benefit from their removal, pay their fair share of the costs of waste disposal through electricity generation. Ratepayers should pay for the cost of power from which they benefit, but not the producer's cost for producing electricity.

ENDNOTES

1. California Energy Commission, *1991 Biomass Resource Assessment Report for California*, December, 1992.

2. UCLA-BFP Forecast, *The California Long-Term outlook: Projections to 2010*, September 1996.

3. California Energy Commission, *Historical and Forecasted GHG Emissions Inventories for California*, January, 1997.

4. California Integrated Waste Management Board, *Integrated Waste Management Board 1995 Annual Report, The Quiet Revolution in Waste Management*, April 1996.

5. California Department of Finance, *Projected Total Population of California Counties: 1990 to 2040*, May 1993.

6. UCLA-BFP Forecast, *The California Long-Term Outlook: Projections to 2010*, September 1996. Table 6. California Nondurables Manufacturing Employment, Leather component (SIC31).

7. California Integrated Waste Management Board, *1995 Annual Report*, 1995.

8. California Integrated Waste Management Board, Policy and Analysis Office, *Railhaul Status Report*, May 1996.

9. California Integrated Waste Management Board, *Meeting the 50 Percent Challenge: Recycling Market Development Strategies Through the Year 2000*, August 1996.

10. U.S. Environmental Protection Agency, *Greenhouse Gas Emissions from Municipl Waste Management*, Draft, March 1997.

Chapter VI

Reducing Greenhouse Gas Emissions from Transportation

Introduction

California's transportation sector is the largest single contributor to both criteria air pollutants and carbon dioxide. In comparison to the national transportation sector which, according to the U.S. Department of Transportation, accounts for 32 percent of CO_2 emissions,[1] California's total transportation use produces 56.5 percent of all CO_2 in the state. California's transportation use has escalated over the past 20 years (aside from a temporary decrease from 1979 to 1981 prompted by the oil crisis) beyond all expectations, primarily as a result of explosive population growth. Projected in the 1980s to exceed 30 million by 2000, the state's population had grown well beyond that threshold by 1990 and is expected to reach more than 49 million by 2002. The household composition in the state has also seen dramatic changes. Growth in single-parent households and increased numbers of working adults in each household have greatly expanded the number of automobiles per family and the number of vehicle trips per household.

Although stringent air quality standards have led to vehicle and fuel technologies that greatly reduced criteria air pollutants (CO, hydrocarbons, and nitrogen oxides), concurrent reductions have not occurred in emissions of CO_2 resulting from the production and use of transportation fuels. For example, reformulated gasoline, which emits 15 percent less smog-forming pollutants per mile than gasoline, provides only a slight decrease (0.6 - 1.1 percent/gallon) in carbon dioxide emissions. Emissions of CO_2 are directly proportional to the amount of fuel consumed; according to a recent study by the American Council for an Energy Efficient Economy, every gallon of gasoline burned releases 26 lbs. of CO_2.

This chapter of the *1997 Global Climate Change Report* further examines strategies relating to policies set forth in the *1991 Report*. Strategies examined were:

1. Developing alternative (low-emission) fuels, vehicles and markets;
2. Promoting electric vehicles and hydrogen fuels;
3. Developing the necessary infrastructure to promote alternative fuel vehicle use;
4. Promoting biomass-based alcohol fuels;
5. Reducing vehicle miles traveled by personal vehicles through fuel/carbon taxes, user fees, or feebates;

6. Increasing vehicle fuel economy;
7. Providing incentives for alternative fuel vehicle use; and,
8. Incorporating long-term transportation needs into land use planning.

VI.1. Alternative Fuel Vehicles

The Commission's *1991 GCC Report* proposed promotion of alternative fuel vehicles (AFVs) as one major strategy for reducing California's emissions of greenhouse gases. Since that report, there have been significant new events affecting the outlook for the development and introduction of AFVs in the state, as well as continued technical analysis and debate regarding their potential GHG implications. This analysis is an update of the 1991 report's AFV discussions, with specific emphasis on: 1) the relative GHG impacts of AFVs and conventionally-fueled vehicles; 2) the current development status and outlook for AFV technologies; and, 3) potential actions to take advantage of the GHG reduction benefits offered by AFVs. The AFV technologies considered in this update include alcohol fuels (methanol and ethanol), natural gas, propane, hydrogen, and electric and hybrid-electric vehicles.

Carbon Emission Benefits of Alternative Fuel Vehicles

The relative emissions of both regulated "criteria" air pollutants and greenhouse gases from alternative fuel and conventional vehicles continue to be analyzed and debated. Even criteria emissions categories are not completely understood or agreed upon, and analysis of GHG emissions is subject to much greater uncertainty and analytical variability. This is partly because, in addition to direct vehicle emissions, there is a need to account for emissions that occur in all stages of the fuel cycle -- fuel production, processing, and distribution. Accurate measurement of emissions for each stage of the fuel cycle defies analytical certainty, and estimates of direct vehicle emissions of CO_2 and other GHGs vary significantly, owing to differences in fuel formulations, vehicle efficiencies, estimating/testing methods, and other factors.

Recognizing this analytical variance, Table VI.1-1 provides a comparison of total fuel cycle CO_2 emissions associated with the various alternative fuels, compared to gasoline and diesel fuel, based on a study recently completed by Acurex Environmental Corporation for the California Air Resources Board.[2] The study appears to offer a consistent set of reasonably-estimated values for comparing total fuel cycle emissions for different fuels that represent typical fuel production and supply processes and current vehicle technology. The implications of these estimates for greenhouse gas emission reduction strategies based on AFVs are summarized in the following discussion.

Alternative Fuel Vehicles in California

While AFVs still represent only a tiny portion (perhaps two-tenths of one per cent, collectively) of California's on-road population of 25 million vehicles, there has been continued progress in developing and commercializing alternative fuel options, especially in the heavy-duty vehicle sector. Much of the discussion in this section is based on research and analysis conducted for the Energy Commission staff draft *Transportation Technology Status Report (TTSR)*.[3] This report is a thorough review of AFV development activities by the worldwide auto industry to date, with particular attention to vehicle options with potential application in California. Table VI.2-2 summarizes a database that inventories over 275 vehicle development projects undertaken by original equipment manufacturers (OEMs) of light-duty and heavy-duty motor vehicles. For each alternative fuel, the table shows the number of current commercially-available vehicle models in California, along with numbers of models with announced market introductions, models available in foreign markets, models undergoing active development, and models previously under development. The following discussion indicate where each fuel technology stands on the continuum of commercial development for the California market and explore the comparative GHG impacts of AFVs and conventionally-fueled vehicles.

Methanol

Methanol burns more efficiently and produces less carbon from combustion than gasoline. However, the natural gas methanol production cycle, the source of all methanol currently being produced, results in somewhat more carbon emissions than the gasoline fuel cycle. The net result, when methanol is used with 15 percent gasoline as M-85 motor fuel, is overall fuel cycle CO_2 emissions similar to gasoline (estimates vary from about 5 percent lower to 5 percent higher than gasoline, indicating no significant difference). Compared to diesel fuel, which operates more efficiently in heavy-duty vehicle engines than gasoline, methanol results in slightly more CO_2 emissions. While methanol use under current supply conditions (from natural gas) does not appear to have either a major positive or negative effect on CO_2 emissions, methanol production from renewable energy sources, such as biomass and landfill gas, which potentially could achieve much lower carbon emissions, continues to be explored. Future prospects for methanol from coal (based on proven technology), an option generally associated with much greater carbon emissions, remain open to consideration.

Only one model of a methanol flexible fuel vehicle (FFV), a Ford Taurus, was available as of the 1997 model year, despite past industry development activities involving over 30 different models, several of which were commercially offered at one time or another. The Taurus FFV represents the single most successful AFV introduced in the U.S. and California to date, with 1996 reported sales of 5,800. This and other previously-marketed methanol FFV models combine for a total California FFV population of over 13,000 vehicles, most used in government and commercial fleets, with a few in the hands of the public. But the future of FFV availability is highly uncertain, with no models besides the Taurus scheduled for introduction or re-introduction at this time.

Meanwhile, previous development activity involving dedicated (methanol-only) light-duty vehicles has all but disappeared. Therefore, while methanol vehicles have successfully attained commercial availability, the methanol vehicle market is hardly assured of continued growth.

Progress with methanol heavy-duty vehicles has also slowed, with no current methanol engine offerings from among at least eight that have been under development. Discontinuation of methanol use by the Los Angeles Metropolitan Transit Authority (LAMTA) bus fleet, the major purchaser of buses with Detroit Diesel Corporation's (DDC) path-breaking methanol engine, has been a major setback. Caterpillar, however, recently announced a new flexible fuel methanol/diesel engine development program, which may renew prospects for heavy-duty methanol vehicles.

Ethanol

Like methanol, ethanol produces less vehicular emissions of CO_2 than gasoline; however, the ethanol fuel cycle has been the subject of intense controversy among researchers with respect to its net efficiency and carbon emissions. This is mostly due to the current practices associated with the U.S. corn-to-ethanol industry, and the use of fossil fuels, including petroleum and coal, in these practices. Analyses have ranged from concluding that ethanol use results in substantially higher, about the same, or somewhat lower CO_2 levels than gasoline use. The Acurex analysis, as summarized in Table VI.1- 1, estimates the current U.S. corn-based ethanol fuel cycle to offer a significant (30 percent) reduction in CO_2, versus gasoline. Realistically, the debate over the effects of corn-produced ethanol may not be significant to the long-term GHG implications of this fuel. Relatively small quantities of fuel-grade ethanol are produced in California from agricultural and food industry waste products. Existing ethanol production elsewhere in the world, most notably from sugar cane in Brazil, probably has much different CO_2 effects than traditional U.S. production from corn. Given that new ethanol production processes and feedstocks continue to be pursued, with the primary goal of reducing production costs, U.S. ethanol production could ultimately be conducted on a more "truly-renewable" basis, greatly reducing net carbon emissions.

Ethanol's direct use as a motor fuel in California has been mostly limited to only a few demonstration vehicles. An ethanol-fueled Ford Taurus FFV is available, although few, if any, are being operated in California. Ford is also preparing to offer the Windstar Van and General Motors the S-10 pickup as ethanol FFVs, but their availability in California remains to be determined. Ethanol continues to be used by some refiners as a gasoline oxygenate additive, although little ethanol-blended gasoline is reportedly being marketed in California at this time.

On the heavy-duty vehicle side, the Los Angeles Metropolitan Transportation Authority (LAMTA) is currently replacing methanol with ethanol in its alcohol-fueled bus fleet, and is reportedly ordering additional ethanol buses. If the LAMTA becomes a permanent ethanol user, other heavy-duty vehicle fleets in the state may also opt to use this fuel.

Table VI.1-1: Estimated CO_2 Emissions from Vehicle Fuel Cycles (1)
Grams per Mile (2)

	Vehicle	Fuel Cycle	Total
Gasoline (CA RFG)	307	46	353
Diesel	270	22	292
Methanol (as M-85) from Natural Gas	297	75	372
Ethanol (as E-85) from Corn	51(3)	186	237
Compressed Natural Gas	246	39	285
Liquefied Natural Gas	240	10	250
Liquefied Petroleum Gas	281	10	291
Hydrogen from Natural Gas	0	217	217
Electricity (4)	0	198	198

(1) Source: Evaluation of Fuel-Cycle Emissions On A Reactivity Basis, Acurex Environmental Corp. for the California Air Resources Board, September 19, 1996

(2) Grams per Mile based on gasoline fuel economy of 27.5 mpg; energy-equivalent fuel economy for the other combustion fuels

(3) Vehicle emissions for ethanol reduced to reflect recycle of CO2 in biomass cultivation

(4) Electricity production emissions based on supplying an electric vehicle requiring 0.35 kilowatt-hour per mile

Table VI.1-2: Summary of OEM Industry Alternative Fuel Development Projects Undertaken in 1980s/90s

Light-Duty Vehicles						
Commercially Available						
Models (in CA, 1997)	1	1	4			4
Additional Models w/						
Scheduled (US/CA) intro's		1	2			2
Models Available Only in						
Foreign Countries		3	4	7		10
Other Models Under						
Active Development		1	4	5	1	35
Inactive (or status uncertain)						
Development Models	33	3	11	2	7	39
Total Development Models						
Listed in Inventory	34	9	25	14	8	90
Heavy-Duty Vehicles and Engines						
Commercially Available						
Models (in CA, 1996)		1	17	3		1
Additional Models w/						
Scheduled (US/CA) Intro's			8	2		
Models Available Only In						
Foreign Countries		1	3	2		
Other Models Under	1					
Active Development		1	11	7	3	19
Inactive (or status uncertain)						
Development Models	7	1	6			2
Total Development Models						
Listed in Inventory	8	4	45	14	3	22

Natural Gas

Natural gas vehicles offer perhaps the most straightforward margin of carbon emission reduction of any AFV category -- about 20 percent versus gasoline and 12 percent versus diesel. Even after accounting for the input energy to compress (or liquify) natural gas for storage as a motor fuel, natural gas vehicles result in this level of CO_2 reduction. LNG, being developed primarily for heavy-duty vehicle applications, is estimated to offer about a 14 percent CO_2 benefit, versus diesel. The continuing debate over the importance of methane emissions, which are higher from the natural gas fuel cycle, and firm determination of the relative efficiencies of natural gas engines could affect this advantage.

California has an estimated 4,000 light-duty vehicles fueled with compressed natural gas (CNG), most converted from gasoline vehicles and operated by fleets. Four models of new CNG automobiles and light trucks are currently being offered by Ford, and two additional OEM CNG models are scheduled for introduction. The high incremental prices of these CNG models, so far, appears to be restricting market sales; unless sales are increased, continued growth of the state's CNG vehicle population is not assured. Further conversion of new vehicles to natural gas is presently stalled due to California Air Resources Board (CARB) emission certification requirements.

Heavy-duty natural gas vehicles, using both CNG and LNG (liquified natural gas), are currently achieving the most commercial progress of any AFV type, driven by increasing pressure to control heavy-duty vehicle NOx and particulate emissions as shown in Table VI.2-2. Six different manufacturers of heavy-duty engines are offering natural gas engine options, and 17 different models of OEM buses and trucks are available in California. Eight more models are scheduled for introduction, and 11 others are under active development.

Liquefied Petroleum Gas

As indicated by the Acurex study results (a 27 percent reduction in fuel-cycle CO_2 emissions over gasoline vehicles), most estimates accord LPG a substantial emissions benefit. Determining LPG's effects is complicated by several factors, including the variability of the composition of this fuel in the marketplace and its multiple sources as a byproduct of natural gas production and petroleum refining. California is in the process of implementing a fuel quality standard for LPG motor fuel, which may help confirm its carbon emission characteristics. LPG has been the most widely used alternative motor fuel in California to date. Estimates (unverified) are that as many as 40,000 vehicles have been converted to use this fuel; however, vehicle conversions have virtually been suspended, due to the CARB's emission certification requirements, and there is no assurance that an LPG vehicle population will be maintained in the state. Both light and heavy-duty OEM LPG vehicle options have also been scarce, with Ford's market offerings of a LPG pickup truck model and a medium-duty truck chassis currently in flux.

Hydrogen

Hydrogen emits no carbon from fuel, and only traces of carbon from engine oil consumption, making it essentially a zero carbon-emitting fuel, in properly operating engines. Currently, nearly all hydrogen being produced (mostly for industrial gas markets) is made from natural gas and, although not well quantified, CO_2 emissions associated with this method of production are significant. Even so, hydrogen vehicles using natural gas-based hydrogen probably offer significantly lower fuel-cycle CO_2 emissions than gasoline vehicles (nearly 40 percent lower, according to the Acurex study). More optimistic visions of future hydrogen energy use, either as a direct vehicle fuel or for fuel-cell electric vehicles, assume that the hydrogen would come not from natural gas, but from electrolysis of water, preferably using solar energy[4] or other renewable sources of primary process energy. This process is estimated to produce one of the lowest levels of CO_2 emissions of all fuel-cycles. Many fuel-cell demonstrations involve on-board production of hydrogen from other fuels (e.g., methanol, gasoline), which would result in emissions closer to those of the fuels being used.

Hydrogen continues to be an experimental motor fuel, with no vehicle models under development for commercial market introduction. At least three OEM companies, Mercedes-Benz, BMW and Mazda, have demonstrated hydrogen-fueled vehicles. Other research entities, including the University of California, Riverside, maintain active hydrogen vehicle programs. There is no reliable prediction of when,or if, hydrogen vehicle technology might become commercially available. Hydrogen is also being experimentally applied, in several projects, as an intermediate fuel for fuel cells powering hybrid electric vehicles.

Electric Vehicles

Electric vehicles present the most complex case of any alternative fuel category for determining CO_2 emissions. While battery-powered EVs can be accurately called "zero-emission vehicles" when considering direct vehicle emissions, power plants using fossil fuels to generate electricity for EV charging produce indirect emissions from EV use. Projections of supply sources for EV charging in California indicate that much of the new electricity generated will come from natural gas-burning power plants, for the foreseeable future. Other contributing supply sources may include coal-burning power plants outside the state and, to a lesser degree, non-fossil fuel sources (nuclear, hydroelectric, geothermal, wind, and solar), within and outside California.

A simplified way of comparing CO_2 effects from EVs is to assume the electricity comes from a natural gas power plant. Under this simplified analysis, EVs used in place of gasoline vehicles would result in approximately 30 percent less CO_2 emissions and, where EVs replace diesel-fueled vehicles (e.g. electric buses), about 20 percent less CO_2 would result. This also assumes the current average energy efficiency of natural gas electric generation; future improvements in efficiency could yield larger CO_2 reductions. To the extent that coal power plants contribute to the electricity mix, the rate of CO_2 emissions will be much higher, while any contributions from non-fossil sources will have negligible levels of CO_2.

Besides the sources and efficiency of electricity supply, other factors, especially operating efficiencies, affect estimates of CO_2 emissions resulting from EVs. Electricity use rates of vehicles varies from less than 1/4 kilowatt-hour per mile to over 1.5 kWh/mile, analogous to the wide range of fuel economies of conventional motor vehicles. CO_2 emissions are proportional to vehicle energy consumption, and thus it is important to compare EV and other types of vehicles' emissions on an appropriate energy-equivalent basis, something that has eluded analyses to date. The Acurex study estimates than an EV using 0.35 kilowatt hours per mile of electricity from California's electricity system would produce about 44 percent less fuel-cycle carbon dioxide emissions than a gasoline vehicle with a fuel economy of 27.5 mpg. This result depends on the relative energy consumption levels assumed for an EV and its gasoline counterpart; for example, if the equivalent is 0.36 kWh/mile of EV energy to gasoline fuel economy of 34 mpg (another plausible assumption), the estimated CO_2 benefit drops to about 30 percent.

Hybrid-electric vehicle technologies, involving on-board generation of all or part of the required electricity, present additional complications for estimating CO_2 emissions. Experimental hybrid EVs employing spark-ignited internal combustion engines, turbine engines, and fuel cells are under development, each with unique features affecting carbon dioxide production. This report has not attempted to evaluate the GHG implications of this category of vehicles. A companion report on Ultra-Hybrid Electric Vehicle technologies was prepared by the University of California Davis, under subcontract to the California Air Resources Board (CARB), and submitted to the EPA in December, 1997. Please see the *Draft CARB Report*, *Assessment of GHG Reduction Potential of Ultra-Clean Hybrid-Electric Vehicles* for complete analysis of these technologies.

As a result of California's impending zero-emission vehicle (ZEV) requirements, electric vehicle (EV) development is, by far, the major focus of the automotive industry's AFV activity. While on-road EVs currently in use in the state still number in the hundreds, at least 35 EV models are under active development by the worldwide automotive industry. The high introductory prices of EV models to date, along with the limited ranges of current battery technologies, continue to pose uncertainties for large-scale EV market potential. Considerable EV development is also in evidence in the heavy-duty vehicle sector. While only one model of bus is currently in limited production by a California company, APS Systems, there are at least 19 other active heavy-duty EV development projects, primarily buses.

Conclusions

California has been in the forefront of U.S. and world efforts to develop and apply AFV technologies although, so far, the chief focus of these efforts has been on reducing conventional urban air pollution and introducing petroleum energy-displacing options, rather than reducing GHG emissions. Therefore, while the state's AFV development strategies pursued to date appear to offer marginal carbon reduction benefits, they were not specifically designed, and cannot be expected, to deliver large-scale reductions in transportation sector carbon emissions. If their expanded development and application is pursued more aggressively, with CO_2 emissions reduction as an additional major goal, alternative fuels have the potential to contribute significantly to greenhouse gas reductions. A brief discussion of actions that could give specific AFVs a larger role in a state carbon-reduction strategy follows.

AFV Strategies to Reduce CO_2 Emissions

Methanol

Despite continuing state efforts to advance methanol through cooperative activities with fuel suppliers, auto makers and fleet operators, expanded inroads for this fuel's use in transportation in California are currently in doubt. Methanol fuel remains about 35 percent more expensive in the marketplace than gasoline and this, together with the discontinuation of methanol use by LAMTA buses, has caused use to drop substantially from previous levels. If momentum for methanol introduction is to be regained, mechanisms must be found to stimulate vehicle and engine manufacturers to increase offerings of methanol models, while also addressing the price differential in the fuels market. Even if growth can be revitalized, traditional use of this fuel in FFVs and heavy-duty trucks, supplied from natural gas, will have little carbon emission-reducing benefit. Further advancement of methanol as a strategy for reducing transportation sources of carbon and CO_2 would require additional progress in the following areas:

1. Developing methanol production options using renewable resources to replace natural gas as the primary feedstock and to forestall the methanol-from-coal option;

2. Re-emphasizing dedicated methanol vehicle technology, so that methanol can fully substitute for gasoline in vehicles;

3. Further developing technologies for efficient methanol substitution in heavy-duty highway and non-highway applications.

Ethanol

Ethanol use as a direct alternative fuel has been negligible in California, although its use as a gasoline component has reached measurable levels. LAMTA's change from methanol to ethanol buses represents the first significant direct motor fuel application of ethanol in the state. Whether this represents a trend toward the use of ethanol in heavy-duty applications remains to be determined, as does introduction in California of ethanol FFV models currently being offered elsewhere in the U.S. Ethanol production costs remain about twice that of gasoline, and a continuing large federal tax subsidy maintains the currently-limited supply system. In contrast to the beginnings of the statewide fuel distribution network established for methanol, so far there are no publicly-available ethanol fueling facilities in the state. In addition to further progress toward making ethanol and ethanol vehicles more widely-available and cost-competitive, successful development of ethanol processes that minimize fossil fuel inputs, and achieve a continual recycling of carbon between combustion and biomass-based production, would be required to achieve the full potential of ethanol fuels for CO_2 emissions reduction.

Natural Gas

Continued progress in introducing natural gas vehicles and expanding natural gas refueling facilities in the state could provide a measurable carbon emission-reducing benefit. In order to take advantage of this potential, current rates of natural gas vehicle market introduction will need to be accelerated through a combination of expanded, more affordable new vehicle offerings, and/or vehicle conversion options, and broader access to fuel at cost-competitive prices. Additional actions to fully capture the carbon-reducing potential of natural gas as a transportation fuel include:

1. More effectively controlling methane emissions associated with natural gas production and use (and/or better determination of methane's offsetting effect on CO_2 reduction);

2. Continuing to develop more efficient natural gas engine technologies, and better, less costly fuel storage and refueling systems;

3. More broadly exploring and developing natural gas use in transportation applications beyond highway vehicles.

Propane

While propane vehicles may offer a less certain advantage for CO_2 reduction, the technology and fueling infrastructure are well-developed, with potential for expanded use that could provide at least an incremental near-term benefit. Along with more definitive evaluation of the carbon emission effects of LPG vehicles, measures to realize more of the possible benefits associated with this fuel should include:

1. Increasing efforts to expand LPG vehicle availability from auto makers, combined with re-establishing a viable LPG vehicle conversion industry;

2. Pursuing a range of options for expanding LPG supply availability from domestic and foreign natural gas production, refinery production, and use of excess butanes;

3. Developing more efficient LPG engine technology.

Hydrogen

Hydrogen fuel offers the greatest potential for reducing carbon emissions, but is also furthest from commercial use. Vehicle technology for using hydrogen in internal combustion engines has been successfully demonstrated by several auto companies and appears practicable without further major technical breakthroughs. On-board storage systems for hydrogen, to allow adequate driving range, remain a development challenge, but continuing advances indicate favorable technical prospects in this area as well. In order for hydrogen to realize its potential as a non-carbon-emitting energy form--whether as a combustion engine fuel or for fuel cell electric vehicles--major progress will be necessary on economical production of hydrogen, using renewable sources of process energy. Even though hydrogen combustion is carbon-free, producing hydrogen using fossil energy sources as feedstock, or for process energy, negates much of the CO_2 reduction potential of this alternative fuel. Research and development efforts to improve the efficiency and reduce the cost of hydrogen production, using renewable energy sources such as solar and wind, are the key to the continuing promise of hydrogen as a zero carbon-emitting fuel.

Electricity

Current battery-powered electric vehicle technologies, just realizing their first commercial marketing by the OEM auto industry, can provide a measurable carbon emission-reducing effect if supplied with electricity from natural gas-fueled power plants or from lower-emitting electric generation sources. Emerging advanced battery technologies may increase this CO_2 benefit slightly via higher efficiencies and, even more importantly, may increase market acceptance of EVs by extending driving ranges, albeit at a likely higher cost. In contrast, reliance on out-of-state coal burning electricity supply, if continued at current or enhanced levels, could cancel part of the CO_2 benefit of EVs. Introducing hybrid EV technologies in place of battery EVs, depending on the fuel sources and operating efficiencies of the hybrid systems, could also reduce the CO_2 emissions- reduction benefits.

As discussed in Chapter II of this report, California faces a critical juncture for EV introduction in 2003, when current state air quality regulations call for major auto manufacturers to begin supplying "zero-emission vehicles" (presently defined as EVs) as 10 percent of their light-duty vehicle sales in the state. Market acceptance of EVs is now being tested in actuality for the first time, with initial offerings of EV models by General Motors, Ford and Honda. If successful at the level of California's ZEV regulation, EVs would become the most prevalent type of AFV on the state's roads--potentially reaching 1 million after ten years of the regulation.

Beyond measures to ensure that the ZEV regulation succeeds as designed, other actions that could increase carbon emission reductions achieved with EVs include:

1. Adding new non-fossil fueled electric generating facilities, possibly as a result of California's recent initiative to ensure R&D funding over the next several years for such technologies;

2. Installing more efficient natural gas-fueled generation units, in order to raise the operating efficiency of the electricity supply system enough to increase the CO_2 benefit of EVs;

3. Making improvements in the operating efficiencies of EV technologies which, if they exceed progress on other types of vehicles, could make EVs more effective at reducing CO_2 emissions.

Other Strategies

Along with funding research, development and demonstration of alternative fuels and vehicles over the past 20 years, California is employing two other major strategies which could give AFVs a larger role in reducing fossil fuel use and statewide air pollution, and provide the additional benefit of reducing CO_2 emissions. These strategies are to develop an infrastructure to support the alternative fuel vehicle market and to promote the development of biomass-to-alcohol fuel processes and supplies.

1. Alternative Fuel Vehicle Infrastructure Development

Over nearly two decades of developing alternative fuel and vehicle technologies, the Energy Commission has learned that providing infrastructure is critical to their success. Infrastructure includes everything needed to support the vehicles--from fueling or charging facilities, equipment and public service safety standards and service support, to insurance availability. Providing this infrastructure is crucial to meeting both consumer needs and policy goals.

In order to provide the support needed for successful introduction of low-emission vehicles into the transportation market in the state, the California Legislature enacted, and the Governor signed, AB 3052 in September, 1992. The law charged the Energy Commission with developing the *Calfuels Plan*[5] in cooperation with the California Department of Transportation, Public Utilities Commission, California Air Resources Board, other state and local government agencies and the private sector, to develop a consumer recharging and refueling infrastructure master plan to support development, production, and operation of alternative fuel vehicles.

The report examined in detail a variety of infrastructure details for each type of AFV and fuel, including reformulated gas (RFG), EVs, Methanol, Ethanol, CNG, LPG and Hydrogen. Key infrastructure barriers were identified for each vehicle group, and recommendations that would help overcome them were developed and submitted to the Governor and Legislature in September, 1994. The Energy Commission's overall findings were that:

1. The state has a critical role in infrastructure development and deployment, in providing education and training, in demonstrating advanced technologies, and in creating problem resolution forums to reduce institutional barriers;

2. There are no major technology constraints to hinder AFV infrastructure development;

3. Market uncertainty is the biggest issue affecting infrastructure development and expansion; and,

4. A number of actions can be taken that, while not capital-intensive, can help reduce market uncertainty and private investment.

The Energy Commission's primary goal is to facilitate private sector investment in the AFV refueling infrastructure. To achieve this goal, the Commission is supporting selected ongoing initiatives and facilitating partnerships among all interests that would benefit from early investment in this potentially large market. Key areas addressed in the report where government agencies or industry could take action to cost-effectively foster AFV infrastructure development include:

1. development of alternative fuel supplies;
2. minimizing market uncertainty by forecasting alternative fuel supplies and prices;
3. hardware testing and demonstration;
4. public education;
5. mechanic training and certification;
6. training in AFV emergency response;
7. adopting new building, fire and safety codes applying to refueling and recharging;
8. increasing local government awareness of alternative fuels to increase expansion of the fueling network;
9. providing leadership in resolving AFV issues and problems; and,
10. coordinating statewide AFV activities.

The Energy Commission continues to coordinate activities in these areas. One major goal of the *Calfuels Plan* has already been achieved: Building Health and Safety Codes for installing EV chargers have been developed in cooperation with the California State Fire Marshall's Office. A resource guide for local governments, to encourage the acquisition and use of alternative fuel vehicles in fleets, has also been developed. Development of performance standards for AFV infrastructure appliances in currently underway. Other areas in which the *Calfuels Plan* is currently being implemented include support for development of alternative vehicle fuel supplies from renewable energy sources; analysis of supplies and prices of alternative fuels; testing and demonstration of vehicles; and training in emergency response, beginning with electric vehicles.

2. Biomass-to-Alcohol Fuels

The conversion of biomass (*lignocellulosic biomass*) and energy crops to alcohol fuels in California has great potential. Biomass includes agricultural, forestry, urban wood, yard, and municipal solid wastes. Alcohol fuels can be used in internal combustion engines as blends with gasoline, as direct fuels, or as oxygenated derivatives added to gasoline, and can also be employed in fuel cells. Replacing gasoline with alcohol fuels produced from sustainably-grown, renewable sources of cellulosic biomass does not contribute to the accumulation of CO_2. Alcohol blends, which increase the octane of the gasoline with which they are blended, enable gasoline engines to run lean and reduce carbon monoxide emissions by from 10 to 30 percent, depending on the blend.[6] Neat ethanol and methanol have many fuel properties that are desirable (see Table VI.2-3). They provide superior efficiency and performance to gasoline in properly-optimized engines, because they require lower air/fuel ratios, have higher latent heat of vaporization, provide higher octane values, and have lower flame temperatures.

The search for alternatives to disposing of biomass through burning, and the need to avoid catastrophic wildfires and reduce waste materials, landfills, and greenhouse gas emissions, combine to make it prudent to treat biomass as a renewable resource, rather than as a waste material. Furthermore, thinning of forests for timber stand improvement, removal of dead trees, and collecting and harvesting forest slash has many other beneficial environmental consequences.

Methanol from Biomass

At present, methanol is produced primarily from natural gas and, to a lesser extent, from other hydrocarbons such as propane, naphtha, and heavy oil. These technologies have been commercially available since the 1930s and have evolved into efficient, highly selective processes; however, methanol can be produced from almost any carbon-containing resource, including biomass, which is the only renewable methanol feedstock. Significant progress has been made over the past 15 to 20 years in technologies to converting biomass to ethanol or methanol. Although biomass-derived methanol is not produced commercially at present, improved gasification and gas-conditioning technologies offer the potential to reduce methanol production costs, and for alcohol fuels to play an increasingly larger role in reducing transportation sector carbon emissions.

In California, the future of methanol as a transportation fuel is now at a crossroads, poised for further commercialization and yet facing strong competition from other fuels.[7] The greatest uncertainty in the methanol fuel market today, based on concerns about potential ground water contamination, is whether methyl tertiary butyl ether (MTBE) will be restricted or banned from use as an oxygenate for blending in gasoline.[8] If MTBE can no longer be used, ethanol may be the only environmentally-acceptable oxygenate available; however providing the volume of ethanol necessary to meet the needs of the transportation fuels industry in a timely fashion will be exceptionally difficult. While it is clear that sufficient waste biomass is potentially available to meet the need, a phase-in period would be required to develop the necessary conversion capacity.

Ethanol from Biomass

At present, ethanol use in the United States is centered primarily in the Midwest, where excess corn and grain can be converted into fuel. Fuel ethanol production in the United States is about 1.5 million gallons a year. For biomass to ethanol production, basically three hydrolytic processes have been used to convert lignocellulosic biomass to fuel-grade ethanol: concentrated acid processes, enzymatic hydrolysis preceded by chemical and/or physical pre-treatments, and dilute acid complete hydrolysis.[9] In order to make these processes cost effective, especially in a deregulated environment, a combination of thermochemical and fermentation processes may be considered. Advantages of ethanol include its relatively-low toxicity, water solubility, and biodegradability, making the consequence of large fuel spills less environmentally threatening. The National Renewable Energy Laboratory (NREL) envisions that the first commercial biomass-to-ethanol plant may be built by the year 2000.

Conclusions

Adoption of the following strategies to support the production and use of biomass to produce transportation fuels could pave the way to larger-scale introduction of these fuels in the alternative fuel and vehicles market:

1. Carry out a coordinated statewide effort to promote research, development, and commercialization of cost-effective biomass-to-alcohol fuel technologies.[10] The development of a rational biomass-to-alcohol policy is central to coordinating an integrated approach in the state.

2. Promote direct blends with gasoline of ethanol, methanol, and ethyl tertiary butyl ether (ETBE) from biomass.

   Many Midwest service stations sell high octane gasoline blends that contain 10 percent ethanol (gasohol). A near-neat blend (85 percent ethanol mixed with unleaded gasoline) is also being tested. Ethanol can also be used as a feedstock to produce ethyl-tertiary-butyl ether (ETBE), which may become an important constituent in reformulated gasoline. Based on fuel cycle comparisons with reformulated gasoline (RFG) fuels carried out by the NREL, the E 95 (a blend of ethanol and 5 percent gasoline) biomass-ethanol fuel cycle can produce 90 percent less CO_2 emissions than the RFG fuel cycle.[11] E 95 fuel cycles also produce less

NOx, SO_2, particulate matter (PM) than RFG, when emissions from electricity production are included in the fuel cycle analyses.

3. Promote the demonstration and commercialization of cost-effective biomass-to-ethanol fuels.

   New technologies to produce clean synthetic gas may lead to the use of systems very similar to those now used for natural gas. Pre-commercialization studies of biomass-to-ethanol projects are underway in California, including a rice straw project in Gridley, a Quincy Library Group Project using forest residues, and an NREL-STEP2 project using wood waste and the fiber portion of municipal solid

   waste. Market assessments carried out as part of these projects shows strong potential for an ethanol market in California.

4. Promote the demonstration of ethanol-from-biomass FFV's.

   The California Air Resources Board has recently included ethanol-powered vehicles in their strict emissions certification program.[12] The 1997 Ford Taurus E 85 FFV is now certified under Tier I requirements, the baseline for California emission levels. To adhere to Tier I, the vehicle must maintain specific emission levels in three categories, including: 1) non-methane hydrocarbon emissions of no more than 0.25 grams/mile; 2) carbon monoxide emissions of no more than 3.4 g/mile; and, 3) NOx emissions of no more than 0.4 g/mile. The state should continue to promote the demonstration of biomass-produced ethanol in alternative-fuel vehicles.

5. Promote the use of biomass-to-alcohol fuels for fuel cell applications.

   Fuel cells offer a myriad of advantages over internal combustion engines,[13] including: 1) emissions that are several orders of magnitude less than for internal combustion engines, even when the latter are equipped with catalytic converters; 2) fuel use efficiency at least twice that of gasoline-fueled, spark-ignited internal combustion engines, and 1.5 times that of diesel-fueled, compression-ignited engines, greatly reducing on-board fuel storage requirements; and, 3) far less noise than interna combustion engines.

Table VI.1-3: Properties of Methanol,Ethanol, MTBE, ETBE, Iso-octane, and Unleaded Regular Gasoline[14]

Property	Methanol	Ethanol	MTBE	ETBE	Iso-octane	Gasoline
Formula	CH_3OH	C_2H_5OH	$(CH_3)_3COCH_3$	$(CH_3)_3COC_2H_5$	C_8H_{18}	C_4-C_{12}
Molecular weight	32.04	46.07	88.15	102.18	114	
Density kg/m^3 @ 298 K	790	790	740	750	690	720-780
Air/fuel stoichiometric ratio						
Mole basis	7.14	14.29	35.71	42.86	59.5	
Mass basis	6.48	9.02	11.69	12.10	15.1	
Higher heating value MJ/kg	19.92	26.78	35.27	36.03	44.42	41.8-44.0
Lower heating value MJ per liter	15.74	21.16	26.10	27.02	30.65	31.4-33.0
RON	106	106		118	100	91-93
MON	92	89		102	100	82-84
(RON + MON)/2	99	98		110	100	88
Blending RON	135	114-141[a]	118	117-120[b]		
Blending MON	105	86-97[a]	101	101-104[b]		
Atmospheric boiling point K	337.8	351.6	328.6	344.8		
Heat of vaporization MJ/kg	1.1	0.84	0.34		0.41	
Flashpoint K	280	285	245			
Ignition point K	737	697	733			
Pure component		15.85		30.3		
Blending	214+	82.7-186	55.1	20.7-34.5		55.1-103.4
Fuel in water	100	100	4.3	2	negligible	negligible
Water in fuel	100	100	1.4	0.6	negligible	negligible
Water azeotrope, (atm b.p.), K	(none)	351.4	325.4			
Water in azeotrope		4.4	3.2			
weight percent						

a. 10 percent blends.
b. Assumed 12.7 percent blend.

VI.2. Reducing Personal Vehicle Travel, Improving Fuel Economy, and Alternative Fuel Vehicle Incentives

This section examines methods to lower carbon emissions from personal cars and light-duty trucks in California. It offers a quantitative analysis of potential emission reductions associated with various transportation strategies discussed and recommended in the *1991 GCC Report.* In addition, some of these strategies are examined in a social cost-benefit framework.

Unlike other motor vehicle tailpipe pollutants such as oxides of nitrogen and reactive organic gases, carbon dioxide is a necessary by-product of burning diesel and gasoline in an internal combustion engine. Therefore, reducing carbon emissions due to transportation in California requires a reduction in the use of these fuels. Strategies to reduce carbon emissions from light-duty (personal) vehicles (LDVs or PVs) fall into three classes, each of which reduces gasoline use: (1) strategies designed to decrease driving; (2) fuel economy improvements; and (3) providing incentives for increased use of fuels with a lower carbon content per British thermal unit (Btu) than gasoline.

Simulations of various strategies by staff described below make use of the Energy Commission's Personal Vehicle Model (PVM) and CALCARS, vehicle choice/demand/usage models for California.[14] The PVM results described here are documented in the *1993-1994 California Transportation Energy Analysis Report,*[15] referred to below as the TEAR. CALCARS is basically an updated version of the PVM, developed in 1996.[16]

Strategies to Decrease Driving

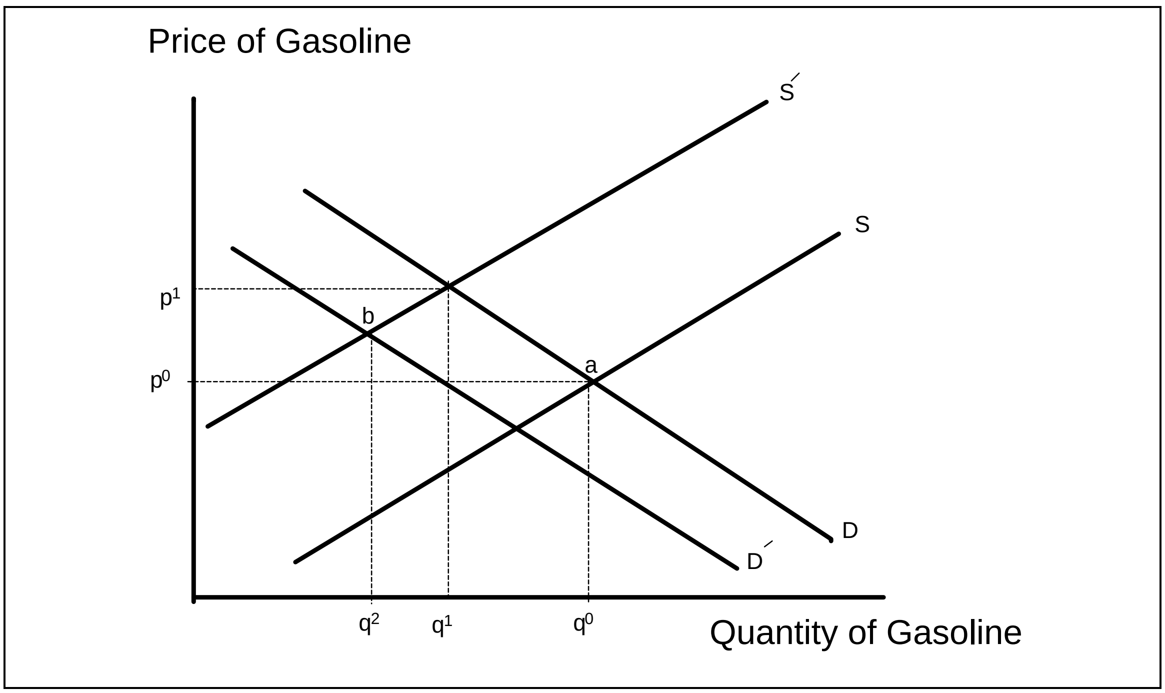
Strategies to reduce travel in light duty, personal vehicles fall into two classes: pricing and increased use of car pooling and transit. Pricing measures raise the cost of driving, which creates an incentive to drive less per vehicle, while car pooling (or ridesharing) and transit move more persons per gallon of gasoline used, using less gasoline and decreasing carbon emissions.

Fuel/Carbon Taxes

According to economic theory, no pricing strategy to reduce greenhouse gases from LDVs would be more efficient than a tax placed on each unit of fuel purchased based on its carbon content.[17] More specifically, the tax per unit of fuel should represent the marginal damage cost of the carbon emissions from its consumption. Fuel use decisions are affected directly as fuel prices would reflect more fully the societal cost of fuel consumption. The marginal cost of driving increases so that LDV vehicle miles traveled (VMT), fuel use and carbon emissions are reduced. In addition to less travel, drivers may reduce their exposure to a tax by buying more fuel-efficient vehicles,[18] which reduces fuel use by an even greater amount.

Figure VI.2-1 shows how this comes about. Initially, at a price of (p_0), drivers of LDVs use a quantity (q_0) of gasoline.

Figure VI.2-1: Effect of a Higher Gasoline Tax



The immediate effect of a tax on gasoline is to shift the supply curve upward to $S^{¢}$ so that quantity of gasoline sold drops to q_1 at the new higher price p_1 as driving is reduced. In the slightly longer term, motorists may switch to more fuel efficient vehicles, so that demand for gasoline falls for any given price. This means that demand shifts toward the left, from D to $D^{\prime}$. The quantity sold of gasoline drops even further, to q_2. In economic terms, this means that the long-run demand curve, containing a and b, is flatter than the short run demand curve, D.

If the gasoline tax is nationwide, an additional effect may be present. In this case, automakers can be expected to provide vehicles with higher fuel efficiency as the tax makes this strategy more profitable. If the tax is imposed in California only, little if any auto manufacturer response can be expected as only a small portion of the market is affected. Note the distinction between the effect from automaker response and the vehicle switching described above. In the latter case, drivers may switch from a “gas-guzzler” to a “gas-sipper”, while in the former both of these vehicles may become more fuel efficient. The effect of this automaker response is to reduce gasoline consumption even further--the long-run demand curve described above becomes even flatter.

For a given gasoline tax, the three effects that can be expected, less driving, vehicle switching, and, in the case of a nationwide tax, automaker response, together determine the elasticity of gasoline demand,[19] along with the reduction in gasoline consumed. The presence of the latter two effects means that the full response to a fuel tax does not occur immediately but over a period of time as motorists adjust their vehicle holdings and (in the nationwide case) automakers improve the fuel efficiency of their products.

CALCARS was used to simulate a tax based on marginal damage cost from carbon emissions by fuel type for both state-only and nationwide cases. Complete results for the state-only case are given in a staff working paper.[20] In the nationwide case, vehicle attributes (e.g., fuel efficiency, acceleration) were modified to be consistent with a higher fuel tax by K.G. Duleep (Energy and Environmental Analysis, Inc.).

Using these results, Table VI.2-1 shows an example of how the three effects described above tend to reduce demand. Both a gasoline-only future and one with significant penetration by alternative fuel vehicles[21] (referred to as the “all fuels” case) were simulated and the results compared with a “base case” forecast. The results presented in the table are based on the gasoline-only case. As there is no reliable estimate of the damage costs of carbon emissions, the cost-of-control estimate of roughly $35 per ton of carbon from ER-94 was used, translating to a gasoline tax increase of approximately 11 cents per gallon (both figures in 1997). Elasticities were used rather than percentage reductions in VMT and gasoline demand as the percentage increase in the price of gasoline due to the carbon tax varied from year to year as the projected base case gasoline price changed, making a direct comparison of these reductions less useful.

Table VI.2-1: Elasticity of Gasoline and Travel Demand With Respect to Fuel Price

	Elasticity of Gasoline Demand		Elasticity of Travel Demand	
Carbon Tax Case	**1997**		**1997**	**2000**
State-Only	-0.131	-0.138	-0.106	-0.097

The elasticity of gasoline demand is higher in absolute magnitude in both years in the nationwide case due to auto manufacturer response. The gasoline elasticity increases in absolute magnitude from 1997-2000 for both cases as motorists switch to more economical vehicles. The resulting increase in average fuel economy reduces the burden of the tax so that VMT drops by a lower percentage than fuel use, and this is reflected in the lower (in absolute magnitude) travel demand elasticities.

Table VI.2-2 shows the carbon emissions per fuel-specific unit assumed for the carbon tax simulation, along with the resulting tax. In addition, the per mile average of carbon emissions by fuel type are shown for 2010, based on the base case forecast for the all fuels scenario. Carbon emissions for electricity represent incremental powerplant system emissions due to electric vehicle use based on an analysis by the Electricity Resource Assessment Office of the Energy Commission.

Table VI.2-2: Carbon Emissions and Resulting Carbon Tax of Each Fuel Type

Fuel	**Carbon Emissions per Fuel-Specific Unit**	**Carbon Tax ($1997)**	**Carbon Emissions per Mile Average* (2010)**
Gasoline	6.1 lbs./gallon	0.11/gallon	0.27 lbs. (22.92 mpg)
Methanol (M85)	3.6 lbs./gallon	0.06/gallon	0.22 lbs. (16.06 mpg)
Compressed Natural Gas (CNG)	4.1 lbs./therm	0.07/therm	0.17 lbs. (24.27 miles/therm)
Electricity	0.35 lbs./kWh	0.006/kWh	0.08 lbs. (4.33 miles/kWh)

* *Per mile average based on projected average fuel economy in 2010 (from the base case forecast). Number in parentheses give this average.*

Sources: *U.S. EPA State Workbook--Methodologies for Estimating Greenhouse Gas Emissions* (January, 1995), and *Global Climate Change Potential Impacts and Policy Recommendations*, Volume II (California Energy Commission, 1991).

Table VI.2-3 gives the projected carbon emission reductions in 2010 for the gasoline-only and all fuels scenarios in the state-only and nationwide tax cases. The percentage reduction in the all fuels cases is slightly larger than in the state-only as the carbon tax creates incentives for switching fuel types as well as switching to a vehicle with higher fuel economy. The carbon reduction in the nationwide cases is more than 50 percent higher than in the state-only cases, demonstrating the increased effect on carbon reductions of a national tax. It should be noted that the penetration of alternative fuel vehicles reduces carbon emissions by around 1.5 percent in the all fuels base case relative to the gasoline-only scenario.

Staff also examined more substantial fuel taxes using the PVM, documented in the TEAR. These cases will be discussed in the section on costs and benefits of transportation strategies, below.

Table VI.2-3: Percentage Reduction in Carbon Emissions in 2010 from CALCARS Simulations of Carbon Tax Relative to Base Case

Fuel Scenario	Tax Scenario	
	State Only	**Nationwide**
Gasoline Only	0.90%	1.39%
All Fuels	0.96%	1.44%

Vehicle Miles Traveled (VMT) Taxes/User Fees

VMT tax proposals usually involve a per mile charge that would be collected annually. Such a tax raises the marginal cost of driving directly and therefore is theoretically the most effective method of reducing VMT. In a comprehensive study for the California Air Resources Board,[22] Deakin and Harvey found that a two cent VMT tax could reduce VMT and fuel use/carbon emissions by four to five percent in 2010, depending on the region within California; however such a tax would present collection difficulties and would require a periodic inspection to determine mileage. More fundamentally, a VMT tax does not target gasoline use directly, so it is not the most efficient method of reducing greenhouse gases. As discussed above, a gasoline tax reduces VMT while, at the same time, providing an incentive to switch to an auto with higher fuel efficiency, further reducing gasoline use.

A congestion fee is a form of VMT tax that would impose per mile charges on heavily traveled roadways during peak periods in an attempt to reduce traffic flow. The result would be less congestion in such areas during rush hours as motorists unwilling to pay the fee switch to transit, an alternate route, or revise their schedules to drive the targeted roadways during non-peak periods. Reducing congestion would improve fuel efficiency, so the percentage reduction in fuel use would likely be greater than that of reducing VMT alone. For example, the analysis by Deakin and Harvey showed that a regionwide congestion pricing scheme for the Los Angeles metropolitan region (19 cents per mile) could reduce gasoline use/carbon emissions by almost ten percent in 2010, while VMT was reduced by around three percent. The implementation of congestion pricing as a strategy in California is discussed further along in this chapter.

Employee parking pricing would impose or increase charges to workers parking at or near the workplace. Such a strategy represents an attempt to remove a hidden subsidy to recover the cost of providing the parking. To the extent that commuters would switch to transit or increase car pooling, VMT and gasoline use would be reduced. Deakin and Harvey's analysis showed that a parking fee, charged to drive-alone commute vehicles of $1.00 and $3.00 per day, could reduce VMT, fuel use, and carbon emissions by around one, two and three percent, respectively.

Expansion of Transit

Transit accounts for about 0.5 percent of transportation fuel consumed in California. While transit systems offer an efficient way of reducing traffic congestion, unless fueled by clean fuels they contribute substantial amounts of criteria air pollutants and CO_2 emissions. Despite California's efforts, primarily by regional and local governments, to exchange diesel-fueled bus fleets for new, clean-fueled fleets (primarily using CNG), CNG-fueled transit represented about 1 percent of the 8,000 buses in service in the state in 1994. About 1,400 heavy rail, light rail and trolley-type electric vehicles were also in use.

Compared to the pricing measures described above, there is less confidence in the transportation literature on the effectiveness of adding high occupancy vehicle (HOV) lanes and/or expanding transit on reducing fuel consumption and carbon emissions, and these measures may have conflicting effects. In a simulation for the Sacramento region on the effects of HOV lanes and transit, evidence suggested that such lanes may actually increase fuel use, by attracting commuters and other travelers away from mass transit. Further, while expanding light-rail and bus transit should reduce total fuel use, it is uncertain as to whether the benefits from this reduction would be sufficient to justify their costs, particularly because these benefits are so dependent on consumer behavioral responses. Given current gasoline prices and parking policies, transit does not appear to be a welcome alternative to automobile travel, especially for middle- and upper-income travelers. Transit travel is typically perceived as inferior to automobile travel with respect to comfort, privacy, and convenience and, despite considerable effort to improve transit amenities and accessibility, transit ridership in California declined by about 5 percent between 1990 and 1994. In a report for the Reason Foundation,[23] Rubin and Moore write, “We contend that nothing short of very major changes in the economic and legal structure of transportation is going to make transit an appealing option for most middle- and upper-income travelers.”

However, the authors do see benefits in expanding and improving bus services, especially if targeted toward low-income travelers. Further, several studies have shown transit ridership may be increased significantly if accompanied by pricing strategies aimed at automobile travel. Johnston and Rodier estimate that expansion of light rail in the Sacramento region (61.5 track miles by 2015) would increase ridership by around 16 percent without pricing strategies, but by over 100 percent if combined with congestion and parking fees and higher fuel taxes.[24]

Fuel Economy Improvements

The following strategies are designed to increase average fleet fuel economy at the manufacturer and/or consumer level and, therefore, to decrease fuel use and carbon emissions.

Increased Cafe Standards

Since 1985, corporate average fuel economy (CAFE) standards for new vehicles have remained at 27.5 miles per gallon for cars, and between 20 and 21 mpg for trucks. Higher standards would affect fuel use gradually; in the first year only new vehicles would be affected, in the second year new and one-year old vehicles, and so on. For the TEAR, staff examined a case where fuel economy increased by around 20 percent for new cars and 10 percent for new light-duty trucks by 2010, relative to the base forecast, using the PVM. The increase in fuel efficiency, which began in 1996 in the simulation, was projected to reduce carbon emissions from light-duty vehicles by 2.5 percent in 2000 and by 7.9 percent in 2010. The decrease in average fuel cost per mile as a result of higher fuel economy was projected to increase total VMT by around 1.5 percent.

Feebates

Feebates, a system of fees and rebates applied to vehicles to induce certain behavior, have been proposed in various states, including California.[25] Legislation in Maryland that would apply feebates, based on fuel efficiency, to new vehicles to reduce gasoline use is the only proposal to make it through the legislative process, but thus far has not been implemented due to court challenges derived from the preeminence of the national CAFE legislation. The popularity of feebates in recent years is due, at least to some degree, to the potential for revenue neutrality--the system can be structured so that the total rebates paid out equal the total fees paid in. Thus, a feebate may be more politically viable than a tax.

Most proposals have targeted fuel efficiency by adding a fee to the price of new “gas-guzzlers” and offering a rebate to buyers of new “gas-sippers.” In this case, the effect of a feebate on overall fuel use increases over time, similar to a higher CAFE strategy. In a gasoline-only world, such a program targets carbon emissions directly, since a vehicle’s carbon output per mile is in direct proportion to per-mile fuel use. In the case of significant alternative fuel penetration, a feebate targeting carbon use would have to vary by fuel efficiency and type.

The staff working paper described above also presents results of a California revenue-neutral feebate program targeting carbon emissions, simulated for 1997 to 2010, using CALCARS. As in the carbon-tax analysis, feebates were simulated for both gasoline-only and all-fuels scenarios. To compare feebates and carbon taxes more directly, the feebate rate (the dollar amount per carbon output per mile--a fee for vehicles with higher than average carbon output and a rebate for autos with less than average output) was set so that the resulting carbon reduction approximately equaled that of the carbon tax by 2010. In the gasoline-only case, the required feebate was around $30,000 per pound of carbon emissions per mile, while the all-fuels case required $23,000. The latter rate is smaller than the former, due to the availability of alternative fuel vehicles--a given rate induces more change in the all-fuels case as new vehicle buyers have the option of lower carbon emitting fuel types, in addition to higher mpg gasoline vehicles. These rates changed vehicle prices by a maximum of about $4,000. Table VI.1-4 shows the gradual impact of the feebate on carbon emissions for both scenarios.

As in the carbon-tax case, nationwide feebates would reduce carbon emissions in California by a larger amount compared to a similarly structured state-only feebate system due to auto manufacturer response, as feebates would increase the cost-effectiveness of adding additional fuel economy to new vehicles. In a study for the Department of Energy,[26] Davis, Levine, and Train used the PVM to simulate a system of nationwide feebates on gasoline LDVs that improved the average fuel economy of new vehicles by 11 to 18 percent by 2010. Of this increase, over 90 percent was due to manufacturer response.

Table VI.2-4: Percentage Reductions in Carbon Emissions from CALCARS Simulations of Carbon-Based Feebates

Year	All Fuels Scenario	Gasoline-Only Scenario
1997	0.09	0.12
2001	0.48	0.59
2005	0.79	0.84
2010	0.98	0.91

Alternative Fuel Vehicle Incentives

As discussed above, staff's projections of alternative fuel vehicle availability in the future lead to a decrease in carbon output relative to a gasoline-only scenario (a decrease of 1.5 percent by 2010). This section discusses the effects on carbon emissions of further AFV incentives.

Fuel Subsidies

Reducing the cost of alternative fuels should increase the ownership of AFVs, as well as VMT per vehicle; however, it should be pointed out that subsidies are normally considered an inefficient method of reducing external costs. Staff examined various fuel subsidies for methanol (M85), compressed natural gas (CNG), and electricity using the PVM, as documented in the TEAR. The scenarios included a 40 and 50 percent subsidy for California only, and a nationwide 50 percent subsidy. The nationwide scenario is again distinguished by automaker response, in this case less fuel efficiency and more performance relative to the base case.

As alternative fuel subsidies without any change in gasoline prices would reduce the average cost of driving, total VMT will likely rise, although gasoline use should decline. It is possible that the increase in carbon emissions from alternative fuel vehicles may more than offset the reduction, due to reduced gasoline use, which was the case in the analysis for TEAR. Table VI.1- 5 shows, from this analysis, the reduction in gasoline use and increase in alternative fuel use, in gasoline equivalent gallons, along with the resulting percentage increases in carbon emissions relative to the base, in 2010.

It should be noted that the largest share of the alternative fuel increase as a result of the subsidies is M85, which on a gasoline-equivalent basis emits about the same amount of carbon (although the higher average fuel efficiency for methanol relative to gasoline vehicles in 2010 means lower carbon output per mile). If the subsidies targeted CNG and/or electricity, carbon emissions might actually drop--although this is not guaranteed, as shown in the next section. It is certainly possible that subsidies for alternative fuels would have to be accompanied by an increase in gasoline taxes in order to guarantee a decline in carbon emissions.

Table VI.2- 5: Projected Effect on Fuel Use and Carbon Emissions of Alternative Fuel Subsidies Relative to Base Forecast in 2010

Alternative Fuel Subsidy	Decrease in Gasoline Use (million gasoline-equivalent gallons)	Increase in Alternative Fuel Use (million gasoline equivalent gallons)	Percentage Increase In Carbon Emissions
40 Percent	1,023	1,235	1.5%
50 Percent	1,377	1,628	1.7%
50 Percent Nationwide	1,537	2,041	3.2%

Vehicle Purchase Incentives

The TEAR also presents an analysis of purchase incentives (no sales tax) for natural gas vehicles fueled by CNG, which has a substantially lower carbon output per gasoline-equivalent gallon than gasoline (4.55 lbs. vs. 6.1 lbs.). Natural gas vehicles are also, on average, projected to be more efficient than gasoline vehicles, which increases the potential for carbon emission reductions. However, as in the case of alternative fuel subsidies, carbon emissions are projected to increase slightly. Although gasoline use is projected to drop by around 11 million gallons in 2010 as a result of the incentive, CNG use rises by 24 million gasoline-equivalent gallons, more than offsetting the decline in carbon emissions from reduced gasoline use.

Costs and Benefits of Transportation Strategies to Reduce Carbon Emissions

TEAR Cost-Benefit Analysis

The strategies described above that offer a reduction in carbon emissions do have other effects that should be considered. In the TEAR, staff performed cost-benefit analyses for various strategies, using the following elements:

- change relative to the base case in consumer surplus;[27]
- change in congestion costs;
- change in air pollution costs;
- tax revenue or subsidy cost[28] (when applicable);
- change in expected cost of oil spills;
- change in energy security costs;
- change in accident costs;
- change in infrastructure/service costs;
- value of change in carbon emissions.

These elements were added together to give a net social benefit relative to the base case. It should be noted that the external costs given here represent staff's best guesses and are subject to varying levels of uncertainty. Secondary effects, such as employment and price effects, were not considered. Table VI.1-6 shows the estimated net benefits for 2010 of the strategies analyzed for the TEAR that were found to reduce carbon emissions (staff did not have the time or resources to do the analysis for every year in the forecast period). Also presented are the percentage reductions in carbon emissions.

The tax cases show net benefits mainly due to the associated reduction in VMT, which would lower costs for congestion, pollution, accident, and infrastructure/services. The higher fuel economy and nationwide tax cases benefit from a reduction in energy security costs.[29]
There are possibly two ways to interpret these numbers in a policy framework. For example, the 50 cent state-only tax reduces carbon emissions by about the same percentage as the higher fuel economy case, but the net benefits are much higher for the former. On the other hand, the 50 cent state-only and the 50 cent national taxes offer about the same amount of net benefits, but the latter strategy reduces carbon emissions much more substantially.
A cost-benefit analysis for congestion fees in the Los Angeles region for 2010 was also undertaken for the TEAR. Simulating a 15 cent per mile average fee during peak periods, staff estimated net benefits of over three billion dollars (1992), mainly due to decreased congestion. Carbon emissions were projected to be reduced by 9.2 percent by 2010.

Carbon Taxes and Feebates

The more recent analysis shows that state-only carbon taxes appear to offer higher net benefits than state-only feebates for a given reduction in carbon emissions, due to the reduction in VMT associated with the tax.[30] It is also important to note that, even with revenue neutrality, feebates reduce private consumer surplus associated with vehicle ownership by creating price distortions. Nationwide feebates, on the other hand, appear to increase consumer surplus as the negative effect from price distortions is more than offset by fuel efficiency increases by manufacturers.

Table VI.2-6: Net Social Benefits and Percentage Carbon Reduction in 2010 for Various Measures Analyzed for the TEAR Relative to the Base Forecast

Case	Net Benefits (1992 $million)	Percent Carbon Reduction
50 Cent Higher Fuel Tax (nationwide)	1,435	14.5
50 Cent Higher Fuel Tax (state-only)	1,433	7.8
40 Cent Higher Fuel Tax (state-only)	1,246	6.2
20 Cent Higher Fuel Tax (nationwide)	901	9.3
20 Cent Higher Fuel Tax (state-only)	719	2.8
Higher Fuel Economy	318	7.9

On the other hand, the state-only feebate is more effective in promoting alternative fuel vehicle demand, particularly for natural gas and electric vehicles, than the carbon tax. Also, the state-only feebate does reduce carbon emissions relative to the base forecast while not exacerbating the external costs related to driving, such as those attributable to congestion.
This is not the case for the nationwide feebates examined by Davis, Levine, and Train, who find that manufacturer response leads to an increase in total VMT as fuel operating costs are reduced for all LDV classes.

Equity Issues

Even when a strategy appears to increase social welfare as a whole, it is important to examine private welfare effects by income class. If a policy places a larger burden on lower income drivers than those with higher income, the policy may not be desirable or some sort of mitigation may be warranted.

Equity concerns are most prevalent when considering pricing measures. Table VI.1-7 compares, for a similar reduction in carbon emissions, the burden of the carbon tax to that of the feebate (in the all fuels case) by income group for 2010, using consumer surplus changes. Both absolute and percentage changes are given. Both the carbon tax and the feebate reduce consumer surplus by larger amounts as income increases, except for the highest income group in the feebate case. Thus, from this perspective, neither strategy appears to place an undue burden on lower-income drivers. However, in the carbon tax case, the percentage reduction in consumer surplus falls as income rises, while this is not true for the feebate simulation. Therefore, the carbon tax appears to be regressive, while the feebate does not. The nationwide feebates examined by Davis, Levine and Train yield consumer surplus increases for all income groups, with percentage increases larger for lower income households than for higher income.

Including travel time savings may increase the disparity in benefits between low and high income travelers. Johnston and Rodier found that pricing measures (a fuel tax combined with congestion and parking fees) reduce welfare for the lowest income travelers, but increase it for those with higher incomes, largely due to a higher value for travel-time savings in the latter group.

Table VI.2-7: All Fuels Simulation Changes in Average Household Consumer Surplus by Income Group in 2010 Relative to Base Forecast

Household Income Group	Carbon Tax (1997$)	Carbon Tax % Change	Feebate (1997$)	Feebate % Change
$0 to $20,000	-$50.24	-0.370%	-$0.25	-0.002%
$20,000 to $50,000	-$62.63	-0.366%	-$1.84	-0.011%
$50,000 to $100,000	-$94.03	-0.324%	-$8.02	-0.028%
Over $100,000	-$106.69	-0.283%	-$5.52	-0.015%

Deakin and Harvey's analysis included an estimate of the per capita daily payment by income quintile for a simulated five-cent VMT tax in the Los Angeles region. Here again, the burden in absolute amounts increased as income rose. However, the analysis does not include a percentage change, so that it is not possible to determine whether or not the tax is regressive.

Conclusions

The following observations reflect the discussion above and raise some important issues with regard to greenhouse gas reduction strategies and policies in the transportation sector:

1. Fuel taxes based on carbon content are theoretically the most efficient pricing strategy in economic terms, since they target greenhouse gases directly;

2. Due to auto manufacturer response, nationwide fuel taxes and feebates appear to reduce carbon emissions by a greater amount than state-only taxes and feebates, respectively, of the same magnitude;

3. Pricing measures and higher fuel economy standards and feebates appear to be effective measures for reducing carbon emissions. Expansion of HOV lanes and transit, as well as monetary incentives for alternative fuel vehicles, may have to be combined with pricing measures to be effective;

4. Fuel taxes and congestion fees may offer significant social benefits, since they reduce congestion and other driving externalities in addition to carbon emissions; however, pricing measures may be regressive;

5. State-only feebates, although reducing consumer surplus, do not appear to affect equity adversely. In addition, feebates may be more effective in promoting alternative fuel vehicle demand than carbon taxes for a given level of carbon reduction; however, such feebates do not appear to reduce driving and, therefore, may not offer the high social benefits of pricing measures. In addition, it is not yet clear whether state-only feebates that increase fuel efficiency will be allowed by the federal government;

6. Nationwide feebates and higher fuel economy standards appear to increase consumer surplus for drivers, while reducing carbon emissions. Such policies reduce the average cost of driving due to manufacturer response and, therefore, may actually increase VMT, exacerbating external costs related to driving;

7. Subsidies for alternative fuels would probably have to be accompanied by increased gasoline taxes, in order to show an overall decline in carbon emissions.

VI.3. Transportation: Land Use and Transportation Efficiency

The *1991 Global Climate Change Report* examined the relationships among land development patterns, increasing demand for transportation services, and increases in carbon emissions from personal vehicles in California. Since 1991, California has developed numerous innovative strategies to respond to these problems, primarily implemented by regional and local government authorities. These strategies include efforts to improve land development patterns that result in increasing demands for transportation services, congestion, and air quality impacts, and to provide alternatives to personal-vehicle transportation.

Many of these programs have only existed for only a few years and were designed with reducing criteria air pollutants and congestion in mind; therefore, their potential mid and long-term success in reducing carbon dioxide emissions is difficult to assess (estimates of CO_2 emissions reductions from other types of transportation strategies have been discussed earlier in this chapter). Research and program audits results have been mixed, and analysis also suggests that the impact of each individual strategy is slight. Ultimately, an integrated approach to evaluating reductions of both criteria pollutant emissions and CO_2 emissions through a wide variety of strategies, specifically keyed to the transportation needs of each region of the state, is essential.

Demographics and Land Use Issues

Two major issues underlying the state's transportation problems are demographic changes and land development market trends. The state's population is expected to increase to 49 million people by the first few years of the 21st century. Household composition in the state has seen dramatic changes; increases in the number of households, due largely to establishment of single-parent households, and increases in the number of employed adults per household, have greatly expanded the number of vehicle trips by families and substantially increased transportation demands.

Other events in the state raised the cost, in the early 1980s, of building housing affordable to middle-income families.   Passage of Proposition 13 in 1978 drastically cut residential property taxes, changing the way public infrastructure (schools, parks, streets, and other services) is financed. The law resulted in making it more profitable for cities and counties to zone land for commercial or industrial development than for residential development, generating funds from local taxable sales to support public infrastructure investments.[31] Because of rising costs both for established urban infrastructure and for additional infrastructure as new development occurred, local governments also began to impose additional fees and other mitigation costs on new construction, to support local revenue demands.

To pay these costs and to maximize profits, developers built higher-cost housing, passing on their costs in the form of higher housing prices. Higher housing costs drove middle-income families employed in urban areas to move further from the urban core, to developing areas where land prices and mitigation fees were lower and, therefore, homes were more affordable. As employees have moved further and further from urban employment centers, vehicle miles traveled to work and for discretionary purposes have increased dramatically.

The single most important result of unprecedented suburban growth in the state has been increased demand for transportation services. Because of costs to construct and maintain the transportation infrastructure, and increasing demand for transportation services generated by low-density suburban housing, supply has not kept pace with demand. Therefore, experimental strategies are being tried to establish new patterns of development that can maintain commercial/industrial revenue support, provide affordable housing and other incentives to attract residents, and decrease the need for a greatly-extended highway transportation infrastructure. Two major strategies have been pursued to change land development patterns: mixed-use development and providing jobs-housing balances.

Mixed-Use and Transit-Oriented Development

Also referred to as "neotraditional" or "pedestrian-pocket" development, the mixed-use urban design concept has become popular among some planners in areas experiencing severe roadway congestion and high levels of air pollution from private vehicles. Proponents argue that pedestrian-friendly community design will decrease reliance on automobiles. Automobile use is de-emphasized by establishing narrower streets, placing garages at the rear of housing, adopting grid patterns for the community, and providing neighborhood-scale commercial development, mixed with residential. The theory is that reintroducing commercial uses into a neighborhood will encourage walking and biking as significant transportation modes to substitute for many trips conventionally conducted by car. Transit-oriented development plans emphasize development along existing public transit lines or in conjunction with planned public transit.

Since 1991, some representatives of both the public and private sectors have employed these design concepts in long-term planning. In California, mixed-use planning is the cornerstone of efforts to develop a coastal area (Playa Vista) in the Los Angeles Basin and the Mission Bay area in San Francisco; an entire pedestrian pocket development (Laguna West) has been initiated in southern Sacramento County; and a neighborhood re-design has been planned in San Diego. Transit-oriented design concepts have also been adopted into city and county General Plans in the state, including the City of San Diego and Sacramento County. Unfortunately, only Laguna West has witnessed any construction, and the recession that affected the California economy from 1991 to 1994 has delayed full build-out of this development.[32] These various design concepts have attracted the attention of the academic community in California and throughout the United States, and a number of studies on their potential have been initiated since 1991.

Studies of the potential effects of mixed-use concepts have focused on comparing travel patterns in established communities that would be replicated in new community designs. In studies conducted on the San Francisco Bay Area, results have been mixed. One study found that grid-like communities actually generated more local automobile trips than conventional communities.[33] Another indicated that, while grid-based communities do provide higher levels of local access, regional commute trips were not affected. In comparing two types of communities along the same Bay Area Rapid Transit (BART) line in the San Francisco Bay Area, the study concluded that the grid-like pattern of the Rockridge Community in Oakland had no higher levels of BART ridership than the conventionally-designed City of Lafayette, located a few miles to the east.[34] A different approach to studying the potential effects of mixed-use concepts recommends that travel behavior and design features be viewed separately, in order to determine the relative contribution of each to reducing private vehicle use.[35] At this time, too few studies, showing ambiguous results, have been completed to lead to any conclusions about the trip-reducing potential of neotraditional development.

Jobs-Housing Balance

This long-range planning concept is based on the proposition that providing a balance of jobs and housing in the same area will reduce vehicle miles traveled by private vehicles. The concept was given policy consideration in the late 1980s by two California regional planning organizations, the Association of Bay Area Governments (ABAG), and the Southern California Association of Governments (SCAG). Due to political considerations, ABAG never adopted jobs-housing balance targets. SCAG, on the other hand, adopted a regional plan in 1989 that called for the redirection of both jobs and housing to begin achieving a balance in the Los Angeles Basin.

Efforts to achieve jobs-housing balances through planning regulations have succeeded, in some cases, in achieving a numerical balance, i.e., the number of jobs equals the number of residents, but not in achieving what one researcher refers to as "self-containment,"or employees living and working in the same community. In his study of the San Francisco Bay Area, Cervero found that jobs and housing actually were relatively balanced. However, in measuring self-containment, he found that, ". . .on average, around twice as many people commuted in and out, as commuted within, cities."[36] SCAG has all but abandoned its goals for redirection of growth to achieve jobs-housing balances, in favor of market-based strategies.[37]

While a direct regulatory approach[38] has apparently failed, there is cause for optimism. A study that reviewed Toronto's success at increasing the level of self-containment within the downtown core concluded that jobs-housing targets may well be achievable if densities near reliable transit services are increased.[39] Others concur with this conclusion, but point out that this is unlikely to occur under current housing market conditions. The prevailing growth trend is one of decentralization, with several minor urban areas forming at the periphery of a large urban area ("edge cities."). Studies have found that densities must approximately double for transit systems, such as light rail, to become economical.[40] So far, regulations for development in most peripheral areas do not allow for the density necessary for public transit to succeed.

Studies on mixed-use and transit-oriented development, and jobs-housing balances, indicate that there is potential for success only with an integrated approach that combines regulatory requirements for density, jobs-housing balances and provision of public transit with market-based strategies, in order to increase the cost of private vehicle transportation to levels designed to encourage public transit use.

State and National Transportation Management Policies and Strategies

Over the past decade, state and federal transportation programs have been targeted largely toward reducing congestion and vehicle miles traveled (VMT) by private vehicles and, as a result, criteria air pollutants. These programs include congestion management plans, transportation demand management strategies, enhanced public transit, and market-based mechanisms, such as congestion pricing.

In 1990, California voters passed Propositions 108, 111, and 116 which included substantial funding for new public transportation projects. Proposition 111 also set requirements for urbanized counties to implement Congestion Management Plans (CMPs) in order to:
1) integrate transportation and land use planning and, 2) provide funding to reduce congestion and air pollution. The CMPs required monitoring of levels of service (LOS) (based on average vehicle speeds) on major highways to trigger local response to increasing congestion. Where a monitored level of service falls below the adopted standard, the local agency is required to prepare a deficiency plan to reduce congestion and restore a higher level of service.

Passage of the national 1991 Intermodal Surface Transportation Efficiency Act (ISTEA) was a watershed event in federal transportation policy. ISTEA authorized approximately $25 billion per year, or $155 billion over 6 years, for all federal transportation programs including highways, transit, safety and research. Approximately $20 billion per year was authorized for surface transportation programs and the national highway system, and $5 billion per year for public transit programs. The ISTEA was guided by federal transportation policies that emphasized the preservation and more efficient use of existing transportation modes; development of multi-modal plans; stronger links between transportation and environmental planning; greater public involvement in local transportation planning; and consideration of the effects of transportation plans and programs on land use, socioeconomic, and environmental issues. ISTEA established major "flexible funding" programs, including the Surface Transportation Program (STP) and the Congestion Mitigation and Air Quality Improvement Program (CMAQ). The STP provides for public road construction and improvement activities, capital costs for transit projects, traffic signal

synchronization, carpool and vanpool projects, parking facilities, and bicycle and pedestrian facilities.
CMAQ provides additional funds specifically for non-attainment air quality areas to implement transportation strategies designed to attain ambient air quality standards by the dates required by California and the Environmental Protection Agency.

The ISTEA also required many of the same things of local agencies as the California law, including Congestion Management Plans, and authorized Metropolitan Planning Organizations (MPOs) as the local agencies responsible for implementing its provisions.[41] Although the national Act provided the legislative mandate and additional funding to expand and enhance regional planning activities, its mandates are far-reaching, and it has taken time for many planners and policy makers to understand and implement its provisions.

As a result of these programs, California's metropolitan areas have been enabled to use Federal Highway Trust Fund Revenues to support a broad range of transportation projects, as determined by regional and local needs. As of 1995, California's MPOs had largely refocused transportation planning efforts to implement provisions of both the California and federal Acts, and metropolitan transportation plans to meet congestion management requirements had been adopted by all major regions of the state. Overall, since 1991, financing for transportation infrastructure has been tied more directly than ever to transportation system improvements in communities. Funding for improvement projects to meet the requirements remains wholly inadequate; further, many current regional and local transportation plans depend on projects that have been on the books, unfunded, for several years.[42]

The ISTEA was up for reauthorization in 1997, with major changes that decrease federal involvement in state and regional transportation planning and funding and provide block grants to states. While many of these changes are designed to provide increased flexibility to states, California MPOs and other transportation authorities have opposed some provisions of the 1997 ISTEA. As currently conceived, the block grants would, by 1999, greatly reduce federal gasoline tax funds currently available for funding a wide variety of state projects The resulting net loss has been estimated to be 9.3 cents/gallon from combined federal and state tax funding levels, amounting to a roughly $1.3 billion revenue loss for the state. This loss would have to be recovered through an increase in the state gas tax, requiring a 2/3 vote of the legislature, or if a local tax, a 2/3 vote of the electorate, and it is extremely uncertain whether this could be accomplished.

Further, federal funding for public transit projects under the proposed ISTEA legislation would be greatly reduced, and replacement of state funds to substitute for federal funds could not be made without a change in California's Constitution (under current California Constitutional Law, state gas taxes can only be used for highway purposes). Finally, state and regional transportation planners strongly support the need for a sustained federal role in transportation policy, including distribution of products to markets, ensuring highway safety, promoting integration of the national highway system with metropolitan transportation systems, protecting national security interests, and ensuring adequate transportation in urban and rural communities.

Transportation Demand Management Strategies

Transportation Demand Management (TDM) strategies have been extensively implemented by regional and local governments since the late 1980s. These strategies seek to reduce the number of private, single-occupant vehicle (SOV) trips by providing incentives to use alternative travel modes, and disincentives for private vehicle use, to employees of large employers. Many communities and regional agencies have adopted policies and regulations requiring TDM participation as a condition of approval for granting use permits, rezoning proposals, and other discretionary approvals for development. Air Quality Management Plans have also conditioned emissions permits on implementation of TDM plans. TDM plans contain a wide variety of strategies, including incentives for ridesharing programs, public transit use, biking, and walking; temporal spreading (intended to shift commercial and commuter vehicle trips into non-peak congestion hours); providing flexible and alternative work schedules for employees; and telecommuting programs that allow employees to work part-time from their homes or from small, multi-purpose offices in their neighborhoods.

The earliest, wide-scale TDM program was initiated in 1988 by the South Coast Air quality Management District (SCAQMD) and Southern California Association of Governments (SCAG) in the Los Angeles area. The region passed Regulation 15, requiring employers with 100 or more workers at any one site to motivate their employees, by providing financial and other incentives, to consider alternatives to solo driving. Qualified employers were required to submit TDM Plans to the SCAQMD on how they intended to increase average vehicle ridership to comply with geographically-determined standards. By June, 1992, 6,200 plans, representing 2.26 million workers within the SCAQMD jurisdiction, had been submitted.

Despite Regulation 15 and subsequent regulations enacted by the South Coast, the Bay Area (Regulation 13) and other regions in California, early efforts on TDM strategies increased ridesharing in the state by insignificant amounts (Regulation 15 increased ridesharing by just one percent during its first two years).[43] 1990 Census data showed that 72 percent of commuters still drove alone. More recent studies have showed that ridesharing (which represented 15 of the 28-percent use of alternative modes in 1990) is currently the number-one alternative to single-occupant vehicle use for California's nearly 14 million daily commuters, and may have more promise than initially thought. In fiscal year 1995-96, California's regional ridesharing agencies attracted 160,000 commuters, resulting in estimated average reductions of 419 million vehicle miles, 20 million gallons of fuel, and 7,000 tons of air pollutants, statewide. Estimated cost/benefit ratios for these programs are good: an investment of $12.4 million in state funds supporting ridesharing programs (1/10 of 1 percent of an annual state transportation investment of $10 billion) is estimated to have reduced direct commute costs, alone, by $155 million.[44]

Telecommuting (or "telework") programs also appear promising. In 1994, based on 1991 levels and assuming that current growth trends would continue, forecasts showed that 5 - 9 percent of workers in California will be telecommuting by 2011. This represents a reduction in annual VMT of between 7 and 11 billion miles, and fuel savings of between 2 - 3 percent. The study further found that, with sufficient policy and institutional support, VMT reductions (and consequent reductions in carbon and other emissions) could increase substantially.[45] With the growth and pervasiveness of telecommunications in the workplace and all aspects of daily life, as well as changing management attitudes toward more flexible worktimes and decentralization of workers, this strategy still holds considerable appeal for responding to California's transportation problems.

The results of TDM strategies have not been studied sufficiently to lead to conclusions about actual reductions in carbon emissions. Further, in the later 1990s, both regulatory and financial support for transportation demand management programs has been reduced in response to growing concerns about the costs to the economy of regulatory programs in the state (one study in Southern California estimated the costs of compliance with trip-reduction and ridesharing regulations to be about $200 million annually[46]). In 1996, in response to these concerns, the California Legislature passed AB 437 (Lewis), rescinding the authority of air districts and regional government organizations to require such programs. The U.S. EPA and the South Coast Air Quality Management Agency also came to a precedent-setting agreement to remove federal requirements for employer-based car-pool incentive programs. Finally, under AB 2419 (Bowles, 1996), the Legislature made Congestion Management Plans voluntary in nature, if a majority of the city council and county supervisors vote to exempt the city or county.

Market-Based Mechanisms

For the past decade, many transportation planners, economists, researchers, academicians and policy-makers have begun to view transportation services as a commodity, like any other, that should be regulated by market principles of supply and demand. "Congestion pricing" is one of several market-based mechanisms (along with employee parking charges,[47] fuel tax increases, and VMT/emissions fees[48]) that have attracted a great deal of attention. The theory behind congestion pricing is that, if commuters are charged higher costs for using the public road system during peak-demand periods, some will choose less-costly alternatives, i.e., ridesharing or public transit, resulting in reduced traffic flow on major freeways and more equal distribution of commuters among various transportation modes. As with high-occupancy vehicle lanes, already in place on many California highways, congestion pricing tends to increase average vehicle speeds. If average freeway speeds increased from 30 to 50 mph, emissions of CO_2 from personal vehicles could be expected to be reduced by 24 percent, and hydrocarbons by 12 percent.[49]

A comprehensive study on the potential for market-based mechanisms, including congestion pricing and other increased fees for driving, to reduce dependence on single-occupant vehicles was completed by the California Air Resources Board (CARB) in 1996. Among other results, two major conclusions of previous research on pricing strategies were confirmed: 1) that most aspects of the price of auto use and its impacts are quite inelastic; and, 2) that very large price increases would be necessary to obtain sizeable reductions in travel.[50] Other researchers have also reported that overall driving costs would have to be drastically increased to substantially reduce vehicle miles traveled.[51] The CARB study cited above showed price-per-mile increases during peak periods to have useful effects. Increases in an average peak-period cost of 10 cents/mile in the Bay Area and 15 cents/mile in Los Angeles were estimated to reduce VMT by 5 percent and nearly 2 percent, respectively. As modest as these decreases seem, such market-based strategies may prove more effective than regulatory attempts to reduce transportation demand. Further, the CARB's study showed that carefully developing and targeting strategies, based on regional differences, was essential. For example, congestion pricing was found to have a potentially greater effect on petroleum fuel and emissions reductions in the Bay Area and South Coast than in the Sacramento and San Diego regions, where ridesharing and improved public transit alternatives appear more promising.

After the 1991 ISTEA eliminated long-standing federal constraints on toll roads, California began demonstrating congestion pricing. One project, a four-lane toll road on State Route 91 between Orange and Riverside Counties, is the first facility in California to be operated by a private company, on a 35-year franchise basis, and the first to implement electronic congestion pricing. The San Diego Association of Governments also opened a congestion-priced, high-occupancy travel lane on the county's I-15 in early 1996. Several state toll roads are scheduled to begin such operations, using electronic toll collection, in 1997, beginning with the Carquinez Straits Bridge in the Bay Area.

The largest congestion pricing project ever undertaken has been planned for the San Francisco Bay Area since 1991. The Bay Bridge Congestion Pricing Project was selected under an ISTEA program to demonstrate the effects of congestion pricing and was appropriated federal funding in the amount of $23.5 million. A major study on the impacts of raising the toll from $1 to $3 projected that traffic would be decreased during morning peak hours by 1,650 vehicles (about 3.2 percent), reducing travel delays by roughly 40 percent.[52] The federal funds and $22 million in additional annual revenues from congestion pricing would support major increases in Bay Area Rapid Transit capacity and other transit and ridesharing services. The state Legislature is currently concerned with the problem of funding seismic retrofits for California's bridges, and legislation authorizing the Bay Area Metropolitan Transportation Commission to begin the project has been delayed.

Transportation System Management

Managing transportation system flow is designed to reduce congestion by evening-out traffic flows on urban streets and freeways during peak commute periods, reducing emissions of criteria air pollutants and, concurrently, would reduce CO_2 emissions from idling or slow-moving vehicles. Four mechanisms for system management have been employed in some of California's major urban areas: traffic signal timing, traffic monitoring and control, freeway ramp metering, and improved obstacle management.

Traffic signal timing mechanisms provide for traffic signals that are synchronized with posted speed limits on urban streets, to avoid stop-and-go driving that creates congestion, increases emissions, and wastes fuel. Under a major, state-funded program begun at the Energy Commission in the late 1970s (the Fuel-Efficient Traffic Signal Management Program, later transferred to Caltrans), traffic signal timing projects have been put in place in numerous urban and suburban areas in the state.

In cooperation with the California Highway Patrol, the California Department of Transportation (Caltrans) has also established traffic control centers in most major urban areas. The centers use remote video cameras, placed in critical locations, to visually monitor traffic. With cooperation from local media, commuters can learn of transportation system dysfunctions resulting from weather, auto accidents, vehicle failures and other causes, and can choose to avoid the congestion by changing routes or commute times.

Freeway ramp metering attempts to smooth and stabilize peak traffic flows by regulating access to urban freeways. Depending on the location, time of day, and extent of congestion, vehicles entering an areas' freeways may be delayed from 3-10 seconds by traffic lights, smoothing traffic flows and decreasing emissions resulting from stop-and-go patterns.

Obstacle management is used extensively in the San Francisco Bay Area to smooth flows and reduce congestion patterns. During peak hours, tow trucks cruise the freeway system, assisting drivers with mechanical breakdowns and minor accidents and rendering whatever assistance is necessary to remove the obstacle and maintain traffic flows. In addition, solar-powered cellular phones are placed along freeway segments at one-mile intervals to facilitate the process by speeding up the identification of the type and location of incidents.

Conclusions

Land development activities in California have, over decades, led to nearly total dependence on the automobile as the primary transportation mode. More recent, innovative statewide transportation policies and strategies have primarily been designed to plan more effectively for long-term transportation needs and to better manage transportation demand and systems, in order to improve the state's air quality and reduce traffic congestion problems. These policies and strategies can, concurrently, reduce emissions of CO_2 and hydrocarbons. Therefore, there is an important connection between further development of California's transportation system and ensuring that the state can reduce GHG contributions from the transportation sector. As the connection between these issues is more firmly established and acknowledged by state government and the state's business, industrial, academic, and environmental interest sectors, steps should be taken to address all of these issues in an integrated fashion.

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17. *Economics of the Public Sector*, by Joseph Stiglitz, 1986, pp. 184-189.

18. The PVM and CALCARS models employ various classes of cars and trucks in the vehicle choice portions of the models, where the classes are distinguished by one or more characteristics, such as interior space, fuel efficiency, and performance (e.g., subcompact car, luxury car, compact pickup). For example, CALCARS currently includes 14 classes of gasoline vehicles and, when alternative fuels are included, 14 alternative fuel classes.

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25. The California proposal, introduced in the Legislature in 1990, was known as "Demand-Based Reductions in Vehicle Emissions Plus Reductions in Carbon Dioxide, or DRIVE+."

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28. The revenue generated by a tax is assumed to be a benefit, recycled back to the public. Similarly, the funds necessary for a subsidy are considered a cost.

29. The effect on energy security of a gasoline reduction strategy appears to be significant only when the strategy is nationwide, as California reductions cannot by themselves affect this cost significantly.

30. The state-only feebate has almost no effect on VMT. The feebate does reduce average operating cost per mile for the personal fleet as a whole by encouraging the ownership of more fuel efficient vehicles, creating an incentive for increased driving. The reduced enjoyment of driving small, more economical vehicles relative to larger, more powerful ones cancels out this incentive.

31. "Commercial and industrial land uses thus tend to generate a fiscal surplus and residential land a deficit. . .California cities benefit considerably from an increase in local taxable sales in place of residential development, and. . . will lean strongly toward retail development." Boarnet,

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CHAPTER VII

Summary: GHG Emissions Reduction Strategies and Conclusions

The California Energy Commission is committed to preserving and enhancing California’s environmental quality by adopting statewide energy policies and promoting strategies that simultaneously can increase energy efficiency, improve air quality and reduce the potential effects of greenhouse gas emissions on the state's economy and environment. This report has evaluated California's current energy policies and programs, programs in other economic sectors, recent changes in the state's energy supply and services structure, and strategies in each sector to reduce emissions of greenhouse gases. The study also evaluated the impacts of California's transportation sector on greenhouse gas emissions and discussed strategies that have significant potential to reduce carbon dioxide emissions resulting from the state's transportation energy use. If current international efforts to set targets for reducing CO_2 and other greenhouse gases are successful, California is well-positioned to take the necessary actions to comply with national standards that may be set for GHG emissions from energy production, generation and use.

The following discussion summarizes the analyses and presents conclusions on GHG emissions reduction strategies evaluated in the report for each energy-economic sector.

Residential and Commercial Emissions Reduction Strategies

Because of California's long-standing commitment to energy efficiency, anticipated energy savings from energy efficiency programs in the residential and commercial sectors over the forecast period are one of the major sources for projecting reduced CO_2 emissions in the state. Energy efficiency investments can provide a high level of energy services for greatly reduced energy use, and most investments in energy efficiency have been cost-effective on their own, even without considering any emissions reduction value.

The analysis in Chapter IV estimated probable energy savings and reductions of CO_2 emissions resulting from different funding levels of publicly-financed electricity and natural gas efficiency programs from 1995 to 2010. Given the current restructuring of the state's electric utility industry, anticipated energy savings and resulting greenhouse gas emissions reductions from the new "market transformation" type programs are speculative. For this sector, therefore, scenarios of various levels of funding of energy efficiency programs are used to deal with this uncertainty.

The three scenarios used for the funding of energy efficiency programs are 1) "1994 Constant Funding;" 2) "1996 Constant Funding;" and, 3) "Declining Funding After 2002" ("Decline After 2002"). The time period covered for each scenario is from 1994 to 2010; key years used to report projected savings are 2000, 2005 and 2010.

The section presented the likely impacts on CO_2 emissions due to both electricity and natural gas demand, and identified technologies that could contribute to future electricity and natural gas savings and reductions in CO_2 emissions. As shown in Table IV.1-2a of Chapter IV, certain energy saving technologies will be promoted by energy efficiency programs. Refrigeration and lighting, and heating, ventilation and air conditioning (HVAC) measures have been cited as major sources of most of the energy savings in the residential and commercial customer classes over the next decade and beyond. Table IV.1-6 combined findings from the analysis of electricity and natural gas energy efficiency scenarios, showing CO_2 emissions from electricity and gas demand and the comparative effects on emissions of the "1994 Constant Funding," "1996 Constant Funding" and "Decline After 2002" scenarios for energy efficiency program funding.

In the year 2000, all scenarios showed the same CO_2 emissions (4 million tons less than if no programs were in place). In 2005, the "1996 Constant Funding" scenario saved 2 million tons more than the scenario where program efforts decline after 2002. In 2010, the "1996 Constant Funding" scenario saved 1 million tons of CO_2, compared to the "1994 Constant Funding" scenario, and saved 3 million tons of CO_2 more than the scenario where program efforts decline after 2002.

Conclusions

As discussed in Chapter II of this report, legislation currently guiding restructuring of the electric industry in California (AB 1890) established an independent Energy Efficiency Board (EEB) to oversee development of energy efficiency programs for the years 1998 to 2002. The Board has set funding minimums for energy efficiency programs for investor-owned electric utilities of $266 million for the four-year period. The amount required is less than the actual expenditures reached at the peak of utility program spending in 1994 ($335 million), but is roughly the same as expenditures authorized by the Public Utilities Commission for 1996 ($240 million). Because of the uncertainty surrounding the effects of restructuring on the state's energy efficiency programs, the following conclusions are somewhat speculative:

1. For the short-term, changes in the electric utility structure and services, including potential energy price changes, could produce feelings of uncertainty and reluctance among residential and commercial consumers to participate in any new energy efficiency programs. Significantly declining prices could reduce energy

saving investments by industrial and residential customers, delaying continued reductions in CO_2.

2. If the Energy Efficiency Board is successful in its market-transformation efforts over the next four years, long-term prospects are good for significant reductions in energy use through energy efficiency programs and associated reductions in CO_2 emissions.

3. California must continue to evaluate the effects of market transformation on publicly-financed energy efficiency programs in the residential and commercial sectors and to support energy efficiency policies and programs that concurrently reduce energy use and carbon dioxide emissions.

Industrial Emissions Reduction Strategies: Voluntary Programs

California's industrial sector, composed of approximately 50,000 businesses, consumes 25 percent of all electricity, and 30 percent of all natural gas, in the state. About 1,200 (3 percent) of these firms are considered to be large energy users and, therefore, contribute a substantial amount of carbon dioxide emissions. No regulations currently govern overall industrial carbon dioxide emissions levels, and existing programs designed to reduce these emissions are largely voluntary. Since the early 1990's, the federal government has sponsored a number of programs in which California state government, including the Energy Commission and other agencies, is participating cooperatively with California's industries. These programs, discussed in detail in Chapter IV of this report, include the National Industrial Competitiveness through Energy, Environment and Economics Program (NICE[3] Program); Motor Challenge Program; Industrial Assessment Centers (IACS) (currently offered by DOE through San Francisco and San Diego State Universities); and the Climate Wise Program, sponsored by both the DOE and EPA.

The *1991 GCC Report* highlighted the potential for the industrial sector to reduce CO_2 emissions by adopting cost-effective, high-efficiency energy technologies. Although industry adoption of these technologies has been slow, a number of voluntary programs have been developed since concerns with global climate change have increased, and new efforts are being made to improve the availability of information on energy-efficient technologies; these trends may tend to increase adoption rates. On the other hand, the impacts of deregulation and restructuring of the electric utility industry are uncertain. These changes could either negatively or positively affect industry actions with regard to energy efficiency, depending on the structure of the new markets and funding available to support industrial energy-efficiency improvements.

Conclusions

1. Although restructuring the state's energy market has heightened California industry's awareness of the potential to reduce electricity costs, it is difficult to predict industry reaction. Demand for energy efficiency and, consequently, emissions improvements may decrease if energy costs are reduced sufficiently to increase payback periods for efficiency measures. Conversely, industry could both seek alternative, less-costly supplies and adopt energy efficiency measures.

2. Since industrial sector programs to reduce CO_2 have been voluntary, with no set targets for reducing emissions, and also because of the uncertainty surrounding changes in publicly-financed funding for energy efficiency programs, there is no way to predict at this time the extent of GHG emissions reductions that could be achieved with specific strategies.

3. California must continue evaluating the effects of the restructured energy industry, potential energy price changes, and other factors on industrial-sector energy efficiency and evaluate and recommend strategies to reduce GHG emissions in the industrial sector.

Alternative California Oil and Natural Gas Production Technologies

Oil and natural gas production contributes about 20 percent of CO_2 emissions from California's industrial sector. As an example, Thermal Enhanced Oil Recovery (TEOR) technology burns approximately one out of every three barrels of oil recovered, resulting in about 0.114 tons of CO_2 emitted per barrel. Strategies to enhance oil and gas recovery have focused on economics; however, some new technologies have the potential to reduce GHG emissions. The three EOR methods that have shown significant commercial potential for recovering oil from known reservoirs are thermal enhanced oil recovery (TEOR), chemical enhanced oil recovery (aka chemical flooding, or CEOR), and gas displacement methods.

Thermal Enhanced Oil Recovery technologies result in a substantial increase of carbon dioxide emissions, while using Chemical Enhanced Oil Recovery technologies reduces net carbon dioxide emissions. The number of active CEOR projects nationally has declined significantly since 1986, and no CEOR oil production has occurred in California since 1994.

This report discussed strategies for reducing emissions from California's oil and natural gas production, and reached the following conclusions:

Conclusions

1. Further research and development on cost-effective CEOR processes, such as polymer flooding and surfactant flooding, and improved oil prices, are the keys to successful commercialization of CEOR.

2. Gas displacement enhanced oil recovery results in sequestering carbon dioxide so that no net CO_2 is produced. In gas displacement EOR, injecting carbon dioxide from fossil fuels is currently considered an acceptable, but costly, option for reducing carbon emissions. Existing ammonia manufacturing and coal gasification plants produce cleaner CO_2 that can be used directly for enhanced oil recovery. The Energy Commission should promote making gas displacement technology more cost-effective and reducing CO_2 emissions by encouraging power producers to work with the oil and gas industry to use these existing resources effectively.

Electric Generation Emissions Reduction Strategies

In comparison with the national average of 40 percent, California's electric generation sector currently represents only 16.3 percent of CO_2 emissions produced in the state. This report further evaluated three strategies endorsed by the Energy Commission in the *1991 GCC Report* to reduce carbon emissions from electricity generation: 1) accounting for environmental externalities and incorporating their values in resource planning and procurement; 2) promoting high-efficiency gas (HEG) generation and, 3) promoting the development and integration of renewable generation technologies into the electricity system.

Accounting for Environmental Externalities

This section of the report discussed the effects of accounting for environmental costs by valuing residual emissions, based on the amount of criteria air pollutants and CO_2 emitted. The analysis also compared private and social costs, based on resource additions planned by investor-owned utilities in California and their comparative CO_2 emissions.

The analysis largely concluded that valuing damages caused by air emissions has little effect on the type of resource additions found to be most cost-effective. As the result of California's severe air quality problems, there are so many areas where ambient air quality standards are violated that a fossil-fueled powerplant sited in California generally must provide offsets for many of the emissions which are assigned damage costs and, further, must use the best available control technology for its source category. The cost of building and operating new powerplants is far higher than installing pollution control equipment on existing powerplants. The analysis did find that valuing these emissions in selecting new resources usually makes new powerplants (which are generally cleaner and more efficient than existing plants) cost effective from 1 to 3 years earlier than they would be otherwise.

The conclusions reached agreed with the Energy Commission's adopted recommendation, as set forth in the *1994 Electricity Report* (November, 1995), that broad-based, market-oriented internalization policies should be established to balance social costs with social benefits. The Energy Commission has further recommended that the state should: establish alternative methods for internalizing externalities, such as marketable permit programs or surcharges on residual emissions; internalize externalities in all sectors, not just electricity production; coordinate an efficient, broad-based, market-oriented internalization policy that crosses regulatory agency boundaries; document the extent and effects of both in-state and out-of-state externalities; and, during the transition period to a market-based electricity structure, continue to use existing tools, such as environmental performance standards, to induce actions consistent with broader market-based methods.

AB 1890, enacted in the fall of 1996, for all practical purposes eliminated California state government's jurisdiction over electricity resource planning and procurement by the utilities and the processes used in ER 94 for valuing air quality externalities. Nevertheless, California statutes are still in place that require the Energy Commission and California Public Utilities Commission to value environmental costs in determining the cost-effectiveness of energy resources. The Energy Commission expects to continue to apply broadly-based, market-oriented environmental policies as a way to balance the social costs and benefits of energy resources.

Conclusions

While the ER 96 proceedings (report to be adopted in 1997) have focused on examining alternative means of balancing social costs and benefits relating to criteria air pollutants, some of staff's proposed findings are also relevant to accounting for CO_2 damages. These findings are:

1. Balancing economic, energy, and environmental concerns remains as valid as it was when the Energy Commission was established 25 years ago. These goals can be better served with an approach to environmental policy consistent with a competitive market and with other state and federal regulations affecting the electric generation industry;

2. The most economically-efficient method to balance social costs and benefits in a competitive electricity market is through the use of economic incentives. Incentives help ensure that siting and operations decisions account for environmental costs, thus promoting economic and environmentally-efficient growth throughout the state;

3. Well-designed incentive programs should include as many emissions sources as possible, given the costs and benefits of including those sources. Including only major sources, such as powerplants, may exclude potentially lower-cost emission reduction opportunities from smaller sources which, in aggregate, contribute a much larger share of emissions;

4. Each source should sustain environmental costs in proportion to the harm from their emissions. When firms bear the total costs of their actions, then siting, operation, and shutdown decisions lead to the most efficient number and types of firms, with appropriate investments in new emissions-reduction strategies.

High-Efficiency Gas Generation Technologies

Although California relies far less on oil and gas for electricity generation than many other states, this sector is still a significant contributor to emissions. Several high-efficiency gas (HEG) generation systems currently under development hold promise for significantly- improved fuel efficiency, and corresponding reductions in carbon dioxide emissions, over conventional steam turbine systems. These systems include combined cycle Conventional Gas Turbines; Advanced Gas Turbine Systems (ATS); Chemically Recuperated Gas Turbine Cycle (CRGT) gas turbine systems; and Fuel Cell/Gas Turbine hybrid systems. For advanced natural gas generation technologies, carbon dioxide emissions will be inversely proportional to the thermal efficiency of the generation cycle.

Combined-cycle gas turbines produce 26 percent less CO_2 emissions than simple-cycle turbines, and 37 percent less CO_2 than standard, steam turbines, at a fuel-efficiency rate of 51 percent (as compared to the conventional steam turbine rate of 32 percent). CRGT can reduce emissions by 41 percent, ATS combined cycle by 47 percent, and a Fuel Cell/Gas Turbine hybrid system by 54 percent, all at over 50 percent efficiency levels.

Conclusions

1. California should continue to support funding for developing and demonstrating advanced, high-efficiency gas turbine technologies and removing impediments to their commercialization.

2. California should continue to promote replacement of less-efficient and more polluting oil and gas generation facilities with new HEG generation technologies, as well as replacing new fossil fuel power plants with these technologies during repowering.

Strategies for Developing and Integrating Renewable Generating Technologies

California has a large and diverse renewable energy resource generation industry. California's energy mix in 1996 included slightly over 29,000 GWh of renewable energy, including solid-fuel biomass, geothermal, wind, small hydro, solar, and municipal solid waste (MSW) facilities, producing 11 percent of the electricity used in California. Figures IV.4 -1 and IV.4 -2 show the relative capacity (MW) and generation (GWh) shares, respectively, of the technologies comprising California's renewable power industry. Over the past two decades, the Energy Commission has strongly promoted research, development, and demonstration of renewable generation technologies, and their integration into the state's electricity system. Further, despite electric utility industry deregulation and restructuring, California is continuing to promote a high percentage of new generation from renewable resources.

As described in more detail in Chapters II and IV of this report, the *1991 GCC Report* recommended expansion of efforts to accelerate renewable energy technologies through research, development, demonstration and commercialization activities. The *1997 Report* describes the potential results of these strategies and the effects of AB 1890 renewable resources policies on GHG emissions. AB 1890 provides for transition-phase funding for renewable resource technologies in the amount of $540 million collected from investor-owned utility (IOU) ratepayers from 1998 to 2002, to support existing, new and emerging renewable electric generation technologies.

While the Energy Commission believes that the renewable resources resulting from recent policies adopted under AB 1890 will tend to reduce GHGs, there will likely be little reduction from the base *Electricity Report 1994* case. Although further analysis is needed on the effects of renewable resources on reducing GHG emissions, and without considering cost-effectiveness or the potential variety of system interactions and non-electricity system impacts, the various renewable options can generally be ranked, with regard to combustion-produced CO_2 emissions, as follows:

Rank

1 **Non-GHG Emission Producers**

Wind, hydro, photovoltaics, nuclear, non-gas solar, liquid geothermal (with gas injection)

2 **Minor GHG Emission Producers**

Gas-assisted solar (no more than 25% gas burn)
Steam geothermal
Biomass (feedstock combusted alternatively)
Landfill gas (feedstock flared or combusted alternatively)
Municipal Solid Waste (MSW) (avoided methane flared or combusted alternatively)

3 **Others**

Other Biomass
Landfill Gas
Fuel cells
MSW
Conventional natural gas plants (boilers)

In comparing these rankings with conventional technologies, advanced natural gas powerplants would fall between Ranks 2 and 3, older gas plants close to Rank 3, and coal and oil-fired facilities below Rank 3.

Conclusions

1. Under restructuring, the level of renewable resources used in the electric generation sector is not expected to differ substantially from renewables additions planned by the utilities in 1994. Comparing available peak capacity from renewables projected for the year 2005 with the 1994 base case (which is based on resources planned under regulatory proceedings) shows a total of 3,520 MW, while the case with AB 1890 policies shows a total of 3,440 MW.

2. While nurturing the growth of California's renewable resources in California remains a strong GHG reduction strategy, consideration must be given to the varying emissions levels and associated costs of different types of renewables when evaluating their effects.

3. Generally, when based solely on CO_2 emissions reductions from electricity generation, renewable resources are preferable to traditional fossil fuels.

4. The Commission will continue to evaluate the impacts of renewable resource additions on reducing GHGs in California. Further analysis will factor in cost-effectiveness, extending to societal cost/benefits, to develop a more accurate ranking of renewable energy supply options with regard to GHG emissions effects.

Forestry Management for Carbon Sequestration and Emissions Reductions

The reduction of forested areas, largely due to human activities, is contributing substantially to CO_2 production and the potential for CO_2 to affect global climate changes. Improved forestry management practices have substantial potential with regard to CO_2 sequestration and emissions-reduction benefits. Chapter V of this report presented a review of forestry-related emissions reduction strategies proposed in the *1991 GCC Report* and discussed the current status of these strategies. The California Department of Forestry and Fire Protection's (DFFP) Forest and Range Resources Assessment Program staff was contacted to provide information on current strategies being undertaken to promote carbon sequestration and CO_2 emissions reductions.

Conclusions

The Energy Commission concurs with and supports the following strategies being considered by the Department of Forestry and Fire Protection:

1. The DFFP should continue to carry out policies and institutional changes related to the management of wildlands, including expanding and improving the California Forest Incentive Program, which promotes planting trees as a method of removing CO_2 from the atmosphere. Methods need to be developed to induce private landowners to participate, including revising tax policies to provide incentives; removing restrictions on species for which cost-sharing for planting is available; and developing coordinated state and federal programs which will provide

effective strategies to assist in reducing CO_2 emissions, while maintaining viable forests and a successful forest products industry.

2. The Department should further develop agroforestry/biomass energy programs and reinstate a Statewide Biomass Program to stimulate interest and investment in biomass production and use through pilot projects; providing public education and information; investigating and developing incentives for using wastewater for irrigation of biomass crops; and providing incentives to make biomass an economically-viable alternative to other sources of fuel.

3. Urban trees can be 15 times more effective in reducing carbon dioxide than trees in forests, because they reduce heat islands in urban areas and energy use for cooling. New strategies should be developed to make Urban Tree Planting Programs more widespread and effective, including:

    - requiring tree planting elements in local General Plans; requiring new school buildings to incorporate tree planting;
    - mandating "tree space" in every development project;
    - providing tax credits and other incentives to energy producers to develop or expand urban tree planting programs;
    - requiring planning for trees in parking areas;
    - developing a program to provide incentives for planting available publicly-held lands with trees.

4. The DFFP should continue to work with the California Energy Commission to develop and evaluate the potential for improved forestry management strategies to contribute to reducing CO_2 emissions.

Livestock Management for Methane Emissions Reductions

Methane emissions from livestock are produced both by digestive processes and related manure management practices, and are California's second largest source of emissions. While livestock digestive processes produce a substantial amount of the methane emitted (35 percent in 1994), this source is not currently being controlled or captured. However, methane emissions from manure can be successfully captured and utilized through technologies that use this "biogas" to generate energy. Strategies for reducing methane emissions proposed in the *1991 GCC Report* included 1) encouraging the recovery and collection of methane from livestock waste; and, 2) evaluating different methane recovery systems to determine their effectiveness in reducing methane emissions. The current report further evaluated these strategies in Chapter V.

The collection of methane from anaerobic lagoons (which emit about 75 percent of all methane from manure), using appropriate technologies to slurry and ferment manure and then combining the biogas produced with natural gas to power various types of generators, can reduce emissions from about 300,000 tons to 72,000 tons annually. Although combustion results in substantial CO_2 emissions, methane is 21 times as destructive as CO_2 in producing GHG effects; therefore, based on global warming potential (GWP) calculations used throughout this report, the net total emissions from these types of technologies is still an annual reduction in GHGs of 197.6 thousand tons of methane.

As part of its Biomass Demonstration Program, the Energy Commission has evaluated several anaerobic fermentation projects. Costs for these technologies have been estimated at $.04 - $.08 cents per kWH, or $2.60 - $4.25 cents/MMBtu of energy produced. The capture and use of methane emissions from anaerobic lagoons has the potential to produce 9.9 MMBtu of energy, at a cost of from $130 - $217/ton.

Conclusions

1. Further work is required to develop, commercialize and package off-the-shelf systems for small-scale anaerobic fermentation of manure to produce biogas.

2. California should continue to support research, development, demonstration and evaluation of technologies capable of effectively recovering and using methane generated from livestock and other organic waste.

Solid Waste Management for Methane/CO_2 Reductions

Municipal solid waste in landfills is the largest single source of methane emissions in the state, contributing over 1.4 million tons in 1994, and a small amount of CO_2 emissions (approximately 1 percent). Landfill methane emissions are expected to represent over 64 percent of all methane emissions in the state by the year 2010. In 1989, California's Integrated Waste Management Act set a target for the state's cities and counties to divert 25 percent of landfill by 1995 and 50 percent by the year 2000. The Act required solid waste management and gas collection practices that would 1) reduce sources of emissions,

2) recycle and compost solid waste and, 3) transform or dispose of solid waste in landfills. In 1996, the U.S. EPA also issued rules regulating municipal solid waste landfill gas emissions (New Source Performance Standards and Emissions Guidelines) for both new and existing landfills.

The California Integrated Waste Management Board (CIWMB) has jurisdiction for developing and regulating the state's solid waste management practices, including landfilling, recycling, source reduction, composting and combusting. Most programs are orientated towards waste prevention, recycling and education of the public and local decision-makers. Programs also exist to assist local planning and enforcement agencies and to support market development for recycled materials.

Energy Commission staff consulted with the CIWMB on progress on the strategies adopted by the board and supported in the *1991 GCC Report.* By 1995, CIWMB programs had resulted in reaching the California Waste Management Act's target of 25 percent landfill diversion. CIWMB programs currently include Waste Prevention, "Buy Recycled," Market Development, Used Oil and Household Hazardous Waste, Public Education, Planning and Local Assistance, Local Enforcement Agency, Site Cleanup, and Research and Development programs.

Forecasts for GHG emissions from landfills through 2010 assumed that reasonable progress (a 5 percent reduction annually) would be made through these programs toward the state's 1989 Waste Management Act target of 50 percent reduction in emissions in the year 2000. In addition to these programs, the Commission, in its *1991 GCC Report,* recommended upgrading landfill gas to substitute for pipeline-grade natural gas.

Conclusions

1. The Energy Commission will continue to support the CIWMB in its efforts to meet California's goal of 50 percent landfill diversion by 2000.

2. California state government should analyze the cost-effectiveness of a variety of strategies currently being implemented to manage municipal solid waste. A life-cycle cost analysis, similar to the analysis done by EPA on a national level, should be carried out to determine the costs and benefits associated with each solid waste management strategy California is undertaking.

3. Market analysis should be conducted to estimate revenues to California from the sale of marketable materials resulting from methane source reduction and recycling. This market analysis must, at the very least, be done for source reduction and recycling options. Additional market analyses should be done to determine the

potential for electric generation from the combustion of municipal solid waste or landfill gas.

4. As a result of AB 1890, more biomass, municipal solid waste, and land-fill gas projects should be built and will remain competitive in California's electric industry. The IWMB should continue to analyze and monitor criteria and GHG emissions from waste-based electricity production facilities, work with the air quality agencies to reduce these emissions where appropriate, and develop methods to ensure that those who produce waste materials, or benefit from their removal, pay their fair share of the costs of waste disposal through electricity generation. Ratepayers should pay for the costs of power from which they benefit, but not the producer's cost for producing electricity.

Transportation

Transportation is the largest contributor to carbon dioxide emissions in the state, producing nearly 57 percent of all emissions. Emissions of CO_2 are directly proportional to the amount of fuel used in transportation, e.g., every gallon of gasoline burned directly produces 20 lbs of CO_2, while production processes produce additional carbon emissions. The *1991 Global Climate Change Report* contained numerous policy recommendations for reducing emissions of CO_2 from California's transportation sector. These included reducing vehicle miles traveled by personal vehicles, through a number of different measures; increasing vehicle fuel efficiency; increasing non-highway transportation efficiency; developing alternative (low-emission) fuels, vehicles and markets; promoting biomass-based alcohol fuels, electric vehicles and hydrogen fuels; and incorporating long-term transportation needs into land use planning. Chapter VI of this report further examined strategies relating to these policies and analyzed potential emission reductions associated with the various transportation strategies. In addition, some of these strategies were examined in a social cost-benefit framework.

Alternative Fuel Vehicles

The Energy Commission, in the *1991 GCC Report*, proposed promotion of alternative fuel vehicles (AFVs) as a major strategy for reducing California's emissions of greenhouse gases. The analysis in this report updated the 1991 report's AFV discussions, with specific emphasis on: 1) the current development status and outlook for AFV technologies; 2) the relative GHG impacts of AFVs and conventionally-fueled vehicles; and, 3) potential actions to take advantage of the GHG reduction benefits offered by AFVs. AFV technologies considered include alcohol fuels (methanol and ethanol), natural gas, propane, hydrogen, and electric and hybrid-electric vehicles.

Estimates of direct vehicle emissions of CO_2 and other emissions from various alternative fuels vary significantly, owing to differences in fuel formulations, vehicle efficiencies, estimating/testing methods, and other factors. This report provided a comparison of total fuel cycle CO_2 emissions from various alternative fuels, compared to gasoline and diesel fuel, based on a consistent and widely-accepted set of estimated values.

AFVs still represent only a small portion (perhaps .002 percent) of California's on-road population of 25 million vehicles; however, progress has been continuous in developing and commercializing many alternative fuel options in the state and nationally. According to the Energy Information Administration, AFV use increased nationally by 6 percent between 1993 to 1996, and is expected to increase at an average annual rate of 7.6 percent between 1995 and 1997. Nearly one fourth of all AFVs in use are located in California (51,745) or Texas (32,307). While LPG dominated the AFV field in 1995, representing about 75 percent of all AFV vehicles nationally, if California's zero-emission vehicle (ZEV) regulations succeed in reaching their targets, electric vehicles will dominate the California market.

Conclusions

The following conclusions on strategies relating to promotion of AFVs for reducing transportation carbon sources were reached in this report, for each alternative fuel:

> **Methanol:** Further advancement of methanol as a strategy for reducing transportation sources of carbon would require additional progress in: 1) developing methanol production options using renewable resources to replace natural gas as the primary feedstock and to forestall the methanol-from-coal option; 2) re-emphasizing dedicated methanol vehicle technology, so that methanol can fully substitute for gasoline in vehicles; and, 3) further developing technologies for efficient methanol substitution in heavy-duty highway and non-highway applications.
>
> **Ethanol:** Successful development of ethanol processes that minimize fossil fuel inputs, and achieve a continual recycling of carbon between combustion and biomass-based production, would be required to achieve the full potential of ethanol fuels for CO_2 emissions reduction.
>
> **Natural Gas:** Additional actions to fully capture the carbon-reducing potential of natural gas as a transportation fuel include: 1) more effectively controlling methane emissions associated with natural gas production and use; 2) continuing to develop more efficient natural gas engine technologies, and better, less costly

fuel storage and refueling systems; and, 3) exploring and developing natural gas use in transportation applications other than for highway vehicles.

Propane: Measures to realize more of the possible benefits associated with this fuel should include: 1) expanding LPG vehicle availability from auto makers and re-establishing a viable LPG vehicle conversion industry; 2) pursuing a range of options for expanding LPG supplies from domestic and foreign natural gas production, refinery production, and use of excess butanes; and, 3) developing more efficient LPG engine technology

Hydrogen: For hydrogen fuel to reach its potential, major progress will be necessary on producing it economically. Research and development efforts to improve the efficiency and reduce the cost of hydrogen production, using renewable energy sources, are the key to realizing the potential for commercializing hydrogen as a zero carbon-emitting fuel.

Electricity: If California's zero-emission vehicle (ZEV) regulations are successful, electric vehicles (EVs) would become the most prevalent type of AFV on the state's roads and could reach a population of one million vehicles ten years after the regulations are in place. Beyond measures to ensure that the ZEV regulations succeed as designed, other actions that could increase carbon emission reductions achievable with EVs include:

1. Adding new non-fossil fueled electric generating facilities, possibly as a result of California's recent initiative to ensure R&D funding over the next several years for such technologies.

2. Installing more efficient natural gas-fueled generation units, in order to raise the operating efficiency of the electricity supply system enough to increase the CO_2 benefit of EVs.

3. Making improvements in the operating efficiencies of EV technologies, which could make EVs more effective in reducing CO_2 emissions.

Other AFV Strategies

Two other major strategies discussed in the report to assist in reaching the potential of AFVs to participate in reducing the state's carbon emissions included 1) alternative fuel vehicle infrastructure development and, 2) support for the production and use of biomass to produce transportation fuels.

Alternative Fuel Vehicle Infrastructure

In 1994, the Energy Commission submitted its *Calfuels Plan* to the Governor and Legislature, and is continuing to carry out recommendations of that report. The Energy Commission participated in the development and adoption of new Building Health and Safety Codes for EV chargers and development of a resource guide to encourage the acquisition and use of alternative fuel vehicles in local government fleets. Energy Commission staff is currently involved in development of performance standards for AFV infrastructure appliances; development of alternative vehicle fuel supplies from renewable energy sources; analysis of supplies and prices of alternative fuels; testing and demonstration of vehicles; and training in emergency response for AFVs.

Biomass Transportation Fuels

Converting biomass to alcohol fuels holds substantial promise for alcohol fuels to play an increasingly larger role in reducing transportation-sector carbon emissions. Technologies to convert biomass to ethanol or methanol alcohol fuels have experienced significant progress over the past 15 to 20 years. Although not produced commercially at present, biomass-derived methanol technologies are benefitting from improved gasification and gas-conditioning technologies, which could potentially reduce methanol production costs. Pre-commercialization studies of biomass to ethanol projects are currently underway in California, and market assessments of these projects show strong potential for California to develop a viable ethanol market.

Conclusions

1. **Alternative Fuel Vehicle Infrastructure:** The Energy Commission should continue to carry out the recommendations presented in the *Calfuels Plan* on strategies to assist in developing the necessary infrastructure to cost-effectively foster AFV infrastructure development.

2. **Biomass Fuels:** With regard to biomass-to-alcohol fuels strategies, the Energy Commission should continue to promote coordinated statewide efforts on research, development, demonstration and commercialization of cost-effective biomass-to-alcohol fuel technologies;

   1) coordinated statewide efforts on research, development, demonstration and commercialization of cost-effective biomass-to-alcohol fuel technologies;

2) direct blends with gasoline of ethanol, methanol, and ethyl tertiary butyl ether (ETBE) from biomass;

3) demonstration of biomass-to-ethanol projects;

4) demonstration of ethanol-from-biomass flexible fuel vehicles (FFVs); and,

5) the use of biomass-to-alcohol fuels for fuel cell applications.

Reducing Vehicle Miles Traveled, Increasing Fuel Economy, and Providing Alternative Fuel Vehicle Incentives

Strategies examined to reduce personal vehicle travel included fuel/carbon taxes, VMT taxes/user fees, state or nationwide feebates, and expansion of transit. At the high end, a 50 cent higher, state-only carbon tax on gasoline resulted in a 7.8 percent reduction in carbon emissions, while the same level of a nationwide tax showed a 14.5 percent reduction. VMT taxes, including peak-period congestion fees, were examined in California through a comprehensive study by the California Air Resources Board in 1996, in which the Energy Commission and other state and local government agencies participated. The study found that a direct VMT tax of 2 cents/mile could reduce fuel-use carbon emissions by from 4 - 5 percent in 2010, depending on the region to which it was applied, while a 19-cent per mile congestion pricing fee could reduce fuel-use carbon emissions by almost 10 percent in 2010, and VMT by 3 percent. In addition, raising parking fees for drive-alone commute vehicles by $1.00 - $3.00 per day was found to reduce carbon emissions by about 3 percent.

Feebates, a system of fees and rebates, have been proposed in various states and are somewhat popular, since the system can be structured so that total rebates paid out equal the total fees paid in (are revenue-neutral). Therefore, feebates may be more politically viable than taxes. Fuel economy improvements in personal vehicles resulting from both state-only feebates and federal CAFE standards were analyzed. Based on an increase in fuel efficiency beginning in 1996, a 20 percent increase in fuel economy for new cars, and a 10 percent increase for new light-duty trucks, were expected to reduce carbon emissions by 2.5 percent in 2000, and 7.9 percent in 2010; however, the decrease in average fuel cost per mile, due to higher fuel economy, was also projected to increase total VMT by about 1.5 percent.

The effects of expanded transit on reducing personal vehicle travel have remained unquantifiable. Light-rail and bus transit reduce total fuel use (based on economies of scale, i.e, more passenger miles per gallon of fuel), and additional benefits in reducing carbon emissions come from clean-fuel transit, such as electric light rail and CNG-fueled buses. Acquiring these benefits however, is so dependent on consumer behavior that it is often difficult to justify the costs of transit expansion. Transit travel is typically perceived to be less comfortable and convenient than automobile travel and, despite improvements in amenities and accessibility, transit ridership in California declined by about 5 percent between 1990 and 1994. Many researchers concur that only major changes in the economics of the transportation structure, such as greatly increased prices for automobile travel (e.g, congestion pricing, parking fees, and higher fuel taxes) would significantly expand public transit's share of transportation.

Providing alternative fuel vehicle incentives was also examined as a strategy. Major findings are that reducing the cost of alternative fuels should increase ownership of AFVs, but also VMT per vehicle, since alternative fuel subsidies without any changes in gasoline prices would reduce the average costs of driving. The largest share of alternative fuel increase resulting from subsidies would be in M85, which emits about the same amount of carbon as gasoline (on a gasoline-equivalent basis, although its higher fuel efficiency means lower carbon output per mile). If M85, CNG and electricity are all subsidized, carbon emissions would be expected to rise; however, if subsidies targeted CNG or electric vehicles, carbon emissions might actually drop. It is probable that subsidies for alternative fuels would have to be accompanied by increased gasoline taxes to show an overall decline in carbon emissions.

Conclusions

The following observations reflect the discussion above and raise some important issues with regard to greenhouse gas reduction strategies and policies in the transportation sector:

1. Based on pure economic theory, fuel taxes based on carbon content are the most efficient pricing strategy, since they target greenhouse gases directly.

2. Because of the national/international nature of auto manufacturing, nationwide fuel taxes and feebates would reduce carbon emissions by a greater amount than state-only taxes and feebates of the same magnitude.

3. Pricing measures and higher fuel economy standards and feebates appear effective as measures to reduce carbon emissions. HOV lanes and transit use may have to be expanded, and monetary incentives for alternative fuel vehicles combined with pricing measures, for these measures to be truly effective.

4. Fuel taxes and congestion fees could offer significant social benefits, since they reduce congestion and other driving effects, in addition to carbon emissions. Studies on whether these pricing measures are regressive are inconclusive.

5. Although state-only feebates reduce consumer surplus, they do not appear to affect equity adversely. Further, feebates more effectively promote the demand for alternative fuel vehicles than carbon taxes, for a given level of carbon reduction. Feebates do not appear to reduce driving and, therefore, may not offer the high social benefits of pricing measures. In addition, state-only feebates that increase fuel efficiency may not be allowed by the federal government.

6. Nationwide feebates and higher fuel economy standards appear to reduce carbon emissions and to increase consumer surplus for drivers. These policies, though, reduce the average costs of driving, and as a result may actually increase VMT and the external costs related to driving.

7. Subsidies for alternative fuels would probably have to be accompanied by increased gasoline taxes in order to show an overall decline in carbon emissions.

Land Use and Transportation Planning

Unprecedented suburban growth in the state has been the single most important cause of increased demand for transportation services. In California, transportation produces nearly 57 percent of all CO_2 contributing to global climate change emissions, and strategies targeted to reducing these emissions are a critical component of the state's GHG emission-reduction efforts. Two major strategies have been pursued to directly change land development patterns: mixed-use, transit-oriented development and providing jobs-housing balances.

Findings on the potential for mixed-use concepts to reduce private vehicle trips have been mixed; some studies have showed that more local automobile trips were actually generated than in conventional communities, and others that the design was effective in reducing private vehicle use; still other studies have showed that regional commute trips were not affected and, therefore, that VMT and emissions reductions were insignificant. These ambiguous results cannot lead to any firm conclusions about the potential for neotraditional development to reducing personal vehicle trips, VMT, criteria air pollutants or carbon emissions.

Given the overall trend toward residents working in different cities and communities than those in which they live, jobs/housing balances previously attempted by some regional governments in the state have not achieved their goals. Mixed-use, transit-oriented development and jobs/housing balances appear to have further potential only if combined with strategies to increase the costs of personal vehicle use and encourage increased use of public transit.

Other state and federal transportation strategies that have been targeted largely toward reducing congestion and vehicle miles traveled (VMT) by private vehicles, primarily to reduce criteria air pollutants, can result in reducing carbon emissions. These programs include congestion management plans, transportation demand management strategies, and market-based mechanisms such as congestion pricing.

In 1990, a state initiative set requirements for urbanized counties to implement Congestion Management Plans (CMPs). These plans were to be designed to integrate transportation and land use planning and provide funding to reduce congestion and air pollution. Among other transportation requirements rescinded by California in the mid-'90s, legislation was passed to remove requirements for developing CMPs, if a majority of governments within a county adopts resolutions to exempt themselves from the requirements.

California has implemented many transportation demand management (TDM) strategies through its regional and local governments since the late 1980s. These strategies seek to provide incentives to employees of large employers to use alternative travel modes. They have included ridesharing programs; public transit subsidies for employees; incentives for biking and walking; increased parking fees for single-occupant vehicles (and ridesharing incentives); and providing flexible, alternative work arrangements for employees to shift commutes to off-peak hours or, in the case of telecommuting, allow employees to shift their work location to home or to small, multi-purpose neighborhood offices. Since these strategies were adopted, ridesharing and telecommuting, in particular, have seen significant growth. In the mid-90s, many TDM requirements were modified to effectively rescind previous regulations or to revise the types of measures that can be used to comply with trip reduction requirements. It remains to be seen whether TDM strategies will make a significant contribution, over the long term, in reducing air emissions in the state.

Conclusions on several market-based mechanisms discussed in the report, including fuel/carbon tax increases and VMT/emissions fees, have previously been discussed in this section. One type of market-based mechanism, congestion pricing, is actually being demonstrated on a limited basis in the state. The potential for congestion pricing to reduce VMT, trips and air emissions was modelled through the comprehensive study on market-based mechanisms discussed in Chapter VI of this report. While there is a consensus among most transportation researchers that overall driving costs would have to be drastically increased to substantially reduce private vehicle use, the study found that an increased average peak-period cost of 10 cents/mile in the San Francisco Bay Area and 15 cents/mile in Los Angeles could potentially reduce VMT by 5 percent and nearly 2 percent, respectively. Further, congestion pricing would probably have a greater effect on fuel use and emissions reductions in the San Francisco Bay Area and South Coast than in the Sacramento and San Diego regions.

Finally, a variety of mechanisms for managing the transportation system to improve system flow in ways that can reduce air emissions and congestion have been employed in some of California's major urban areas. These measures include: traffic signal timing, traffic monitoring and control, freeway ramp metering, and improved obstacle management.

Conclusions

1. California's land development trends make it essential for regional and local governments to plan more effectively to meet long-term transportation needs, in ways that will reduce congestion, improve air quality, and reduce CO_2 emissions.

2. California will continue to support a wide variety of transportation strategies to reduce both criteria pollutants and CO_2 emissions. These strategies must be specifically keyed to the individual transportation needs of each region of the state.

3. Results are mixed on the effectiveness of regulations, programs and measures to reduce personal vehicle use, numbers of vehicle trips, VMT, and traffic congestion. The impact of each of these separate strategies may also be slight, which suggests that the state must continue to pursue combinations of the most effective strategies to reduce both harmful air pollutants and CO_2.

4. California should develop an integrated approach to evaluating the effectiveness, costs and benefits of a variety of transportation strategies in reducing congestion, criteria air pollutants and carbon dioxide emissions.